JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIV NOVEMBER, 1912 No. 5

NATURAL GAS, WITH INCIDENTAL REFERENCE TO OTHER BITUMENS.*

BY

I. N. KNAPP, M.E.,
Consulting Engineer.

INTRODUCTORY.

Natural Gas is one of the forms of bitumen or hydrocarbon found in Nature, and cannot well be discussed without reference to other forms, such as petroleum, maltha, asphaltum, and the like.

SECTION I.

HISTORICAL SKETCH OF BITUMEN AND ITS SURFACE INDICATIONS.[1]

History fails to record when the first discoveries of bitumen were made by the human race.

It is mentioned many times in the Bible.[2]

The Greek geographer Strabo speaks of the commerce carried

* Presented at the meeting of the Section of Mining and Metallurgy, held Tuesday, April 9, 1912.

[1] The Tenth Census of U. S., vol. x, chap. i, gives elaborate historical references of bitumen by S. F. Peckham. *Ibid.*, chap. vii, bibliography of bitumen. "Petroleum and its Products," by Redwood, vol. i, sec. i, gives a long historical account of bitumen. The Eleventh Census of U. S. gives elaborate "History of the Use of Natural Gas in U. S."

[2] Genesis, xi, 3; II Maccabees, chap. i, verse 19.

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on to supply the Egyptians with bitumen for the purpose of embalming the dead.

Centuries before the Christian era, Baku was a resort for the fire worshippers of Persia and India, the inflammable gases issuing from the ground being made use of in their ceremonies, and every year thousands of pilgrims travelled to the temples on the peninsula of Apsheron to worship the holy eternal fire.

These pilgrims,[3] in later years, arrived in diminishing numbers until 1880, when the Russian Government put a stop to their entry.

At Surakhany, on the eastern edge of the Baku oil field, stands a historic monument or temple on a site visited by Parsees for no less than 2,500 years. Natural gas was led through masonry channels to chimneys at its four corners and burned; also to altars where burnt sacrifice was made.

The Hindoos in the Rangoon district of India long used petroleum to heal disease, to preserve timber, and to cremate the dead.

At the town of "Self-flowing wells,"[4] in western China, natural gas has been used for evaporating brine from time immemorial.

In 668 A. D. petroleum[5] and asphaltic substances were offered to the Court of the Emperor Tenji from the province of Echigo, Japan.

In the same province the utilization[6] of natural gas was projected in 1613.

Sir Walter Raleigh visited[7] the pitch lake of Trinidad in March, 1595, and recorded that he saw "abundance of stone pitch." And in recent years Peckham[8] has reported: "As the bitumen rises in the centre of the so-called lake it is inflated with gas . . . . the gas cavities are of all sizes, some of them very large, and in the aggregate occupy, at a rough estimate, from one-third to one-half the volume of the pitch."

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[3] "The Oil Fields of Russia," by A. Beeby Thompson, pp. 96, 97.

[4] Tz-lin-ching, Province of Szchnan. See *Eng. and Mining Journal*, vol. 69, 1900, p. 193.

[5] Bulletin No. 61, Jan., 1912, Am. Inst. Mining Engineers, p. 104.

[6] *Ibid.*, p. 127.

[7] "Petroleum and Its Products," by Redwood, vol. i, p. 96.

[8] *Am. Journal of Science*, 4th series, vol. i, p. 193.

In the regions of Trinidad[9] and Venezuela, where pitch lakes occur, natural gas is continually forcing up cones of pitch, and they break at the apex and gas issues that may be lighted and will burn sometimes for days.

This phenomenon may be observed not only in the pitch lakes but in the surrounding land asphalt and swamps.

Fig. 1 is a view in Trinidad of typical cones forced up by gas pressure.

FIG 1.

Typical cones formed by gas, Trinidad, B. W. I.

On November 4, 1911, about midday, a fisherman noticed signs of disturbance[10] in the sea off Erin Point, Trinidad.

About 6 P.M. a great column of fire shot up from the water. The principal gas eruption lasted 15 to 20 minutes. There were intermittent flashes of flame during the night.

The next day it was found an island of about 2½ acres had been formed. A landing party found the place still warm, and by laying down boards were able to examine two cones, 12 to 15 feet high, from which gas was escaping. The air was saturated with the odor of sulphur and oil.

The aborigines of our own country were acquainted with

[9] Letter of Arthur Knapp, July, 1911.

[10] Account given in *New Orleans Times-Democrat*, Nov. 26, 1911.

petroleum and natural gas springs. The French [11] commander of Fort Dusquesne (now Pittsburgh, Pa.) wrote in 1750:

> While descending the Allegany we were invited by the Chief of the Senecas to attend a religious ceremony of his tribe. We landed, and drew up our canoes on a point where a small stream entered the river. The tribe appeared unusually solemn. We marched up the stream about half a league, where the company, a large band, it appeared, had arrived some days before us. Gigantic hills begirt us on every side. The scene was really sublime. The Great Chief then recited the conquests and heroism of their ancestors. The surface of the stream was covered with a thick scum, which, upon applying a torch at a given signal, burst into a complete conflagration. At the sight of the flame the Indians gave forth the triumphant shout that made the hills and valleys re-echo again. Here, then, is revived the ancient fire worship of the East; here, then, are the children of the sun.

The existence of natural gas [12] was well known to the earliest explorers of the Kanawha Valley, West Virginia.

In 1775 Washington, while on a visit here to locate lands granted him for his military services, set apart and deeded to the public forever a square acre of land on which was located a "burning spring." Through some informality his intention in this gift was frustrated.

In this same valley, in 1808, and soon after in the valley of the Muskingum, wells were drilled for brine and many primitive salt works were put in operation.

The method and tools for drilling wells evolved here were the progenitors of the method and tools now used in sinking oil and gas wells in similar formations all over the world.

The description [13] of an oil spring near Cuba, New York, made in 1833, says:

> Gas is constantly escaping through the water, and appears in bubbles upon its surface; it becomes much more abundant and rises in large volume whenever the mud at the bottom is stirred by a pole.

In 1833 Dr. Hildreth [14] gave a very entertaining description of the salt works of Ohio and West Virginia, and of the wells

[11] Henry's "Early and Later History of Petroleum."

[12] West Virginia Survey, vol. i (*a*), part i, page 2.

[13] Benjamin Silliman, Sr., vol. 23, p. 97, Jan., 1833, *Am. Journal of Science.*

[14] Dr. S. P. Hildreth, *Am. Journal of Science,* vol. 24, July, 1833, p. 46.

says: "All salt wells afford more or less of this interesting gas [natural gas], an agent intimately concerned in the free rise of the water, and universally present where salt water is found."

Fredonia, N. Y., has the distinction[15] of being the first place in America where natural gas was used for illumination. When this village was incorporated, its seal was designed to show a gas fixture.

In June, 1825, General Lafayette witnessed the illumination of this village with it after it had then been in domestic use some three or four years.

So far as has been ascertained, the first[16] use of natural gas in manufacturing in America was in "boiling salt" in the Kanawha Valley. Here, in 1841, William Tompkins, while boring for salt, struck a large and steady flow of gas, which was strong enough to force the salt water into a reservoir, from which it could be distributed to his furnace pans. He extemporized a gas holder from a hogshead placed over the salt water reservoir, into which he conveyed the escaping water and gas, the water falling into the reservoir, and the gas was conveyed through a pipe to the furnace and produced an intense heat under the whole row of kettles.

In 1843 a well near the Tompkins well, at a depth of 1,000 feet, threw a column of salt water and gas 150 feet high, and was the first "roarer" on record; and

> For many years[17] this natural flow of gas lifted the salt water 1,000 feet from the bottom of the well, forced it a mile or more through pipes to a salt furnace, raised it into a reservoir, boiled it in the furnace, and lighted the premises all around at night.

Knowledge of the existence[18] of oil and gas in the rocks of Ohio resulted largely from the search of the pioneers for that necessary article, common salt. Thus a well drilled in 1814, near the village of South Olive, Noble County, for brine, found such a pressure of gas that it threw salt water and some oil to a height of from 30 to 40 feet, and these eruptions continued for a period of 25 years. About the same time both oil and

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[15] Dr. Orton, p. 494, *Bulletin N. Y. State Museum*, vol. 6, No. 30.

[16] Eleventh Census, "History of the Use of Natural Gas in U. S.," p. 507.

[17] Quoted from West Virginia Geological Survey, vol. i, a, p. 11.

[18] Geological Survey of Ohio, fourth series, Bulletin 1, p. 31.

gas were discovered in Washington County. Similar results were secured at many points in the southeastern part of the State, but the oil and gas were regarded as a nuisance. The former ruined the brine for the manufacture of salt, and the latter was regarded as too dangerous for use.

At Findlay, Ohio, natural gas was found in October, 1836, in digging a well. In 1838 gas from another water well was conducted by wooden tubes into a fireplace and burned from an old gun barrel. This continued in use for over forty years.

It is interesting to note that evidence of this kind led later to tests at several points, with the result that valuable pools of oil were discovered, and finally the great Trenton limestone field itself.

At Burksville,[19] Kentucky, in 1829, a well drilled for salt struck oil at 300 feet. The drilling tools were lifted out of the well by the force of the gas and a column of oil was thrown to the top of the trees.

About 1841, while some work for the removal of McGrew's Shoals, Tombigbee River, Alabama, was in progress, a well was drilled and oil struck at a depth of 365 feet, "which boiled[20] up very similar to the effervescence of a boiling pot."

Natural gas shows with salt water at the Central, Lower and Upper salt works and the sulphur springs at Jackson, all in Clark County, Alabama.

The Alabama geological[21] reports refer to the salt works, but do not mention the presence of natural gas.

I believe this showing of gas is a "marker" for a nearby oil and gas field in this formation. There has lately been natural gas developed in paying quantity in a lower formation in Fayette County.

The costal plains[22] of Louisiana and Texas contain a vast number of gas springs and a few showings of oil.

The settlers[23] in Texas as far back as 1820 knew of petroleum springs, "and they resorted to the places where it

[19] Sixteenth Annual Report U. S. Geol. Survey, part iv, p. 376.

[20] Said to be from Niles' National Register, Aug. 14, 1841.

[21] Report on the Geology of the Costal Plain of Alabama, by E. A. Smith.

[22] Bulletins 184, 212 and 429, U. S. Geological Survey, treats largely of the Costal Plain.

[23] "Petroleum and Its Products," by Redwood, vol. i, p. 90.

oozed from the ground as a black and pasty mass to gather it, though their only use for it was to grease the axles of their wagons, and to protect their implements from rust."

A notable one of these places was at Sour Lake, Hardin County, where the occurrence of oil, asphalt, and gas had long been known.

Fig. 2 is a view of the Sour Lake; the spots of rippling water are caused by gas bubbling up, but this has now ceased, as the gas pressure has been reduced by drilling wells in the

FIG. 2.

Sour Lake, Texas.

vicinity. The first attempts made in drilling here were failures, although promising indications were found.

After 1901, with increased drilling experience and better appliances, Sour Lake was developed as an oil field, and some 25,000,000 barrels of oil have been produced since.

A small gas spring highly impregnated with sulphuretted hydrogen attracted attention to Spindle Top, a mound near Beaumont, Texas. Prior to 1899 several attempts were made to prospect this mound, but were failures for lack of experience and proper drilling machinery. In 1900 Captain A. F. Lucas drilled a well to prospect for sulphur to a depth of about 600 feet and got a good showing for oil.

A second well, with heavier rotary drilling machinery and more experienced drillers, got oil at between 1,100 and 1,200 feet and became the famous Lucas gusher.

The Spindle Top pool covered about 250 acres and has since yielded some 40,000,000 barrels of oil.

Attempts were made as early[24] as 1869 to drill for oil along the Gulf border, but oil in commercial quantity was not obtained until the Lucas gusher was developed in January, 1901.

FIG. 3.

Gas spring in Lake Felicity, La. This is typical of a large gas spring or escapement in water.

In 1903 I started out to look for oil indications along the Gulf border. I found true gas springs very abundant in Terrebonne Parish, Louisiana.

Fig. 3 shows a gas spring[25] in Lake Felicity, near its west shore. I should say that there was not less than 250 cubic feet of gas escaping per hour. This is typical of a large gas spring or escapement occurring in water.

The guide who showed me this place (Mr. Oscar Price) said that he had known of many of these escapements for over

[24] Geological Survey of Louisiana, Report of 1899, p. 126.

[25] About in Sec. 25, Twp. 20, S. Range 19 East, Terrebonne Parish.

forty years, and they were much the same as to quantity of gas then as now, but that the vents changed somewhat in appearance from time to time, sometimes the gas escaping all at one place, and sometimes at several places, but not very far apart.

Fig. 4 shows a typical gas escapement in a field.

I am confident that such persistent gas springs as those mentioned, with hundreds of others of the same kind that occur

FIG. 4.

Blanchard's plantation, Bayou Terrebonne, La. Typical view of gas escapement in a field.

in that vicinity, mean very extensive and productive oil-and-gas-bearing sands in Terrebonne Parish.

Abundance of gas can be obtained here, in places, by stirring up pools of water from the bottom, as shown by Fig. 5. I lighted this gas and the flame blistered the paint on the boat.

I visited this place several times and no gas could be seen unless the water was agitated or the bottom stirred. Such gas showings, I think, are due entirely to decaying vegetation near the surface, and are not fed from a deep source like the permanent gas springs mentioned.

The earliest settlers[26] of eastern Kansas learned from the Indians that "oil springs" existed in a number of places. Some were counted of wonderful efficacy by them, and the "medicine men" there obtained material to use in their various forms of "practice." These springs were principally in Miami and Wyandotte Counties. In Cherokee County, "Tar Creek" received its name from petroleum indications. I watched oil and gas developments in Kansas from 1895 and drilled over 200 wells. But one surface showing of oil came to my knowl-

FIG. 5.

Gas being stirred up by agitation.

edge, and that was about six miles east of Chanute, where I saw a small showing of thick oil found by a farmer in digging for a cellar. People came to me many times to go and see gas springs. This occurred usually after a dry spell followed by a heavy rain, when the ground was filling up with water. Then crawfish holes in the bottoms, and mole and insect holes in the uplands, would, when conditions were right, show a bubbling that looked the same as gas, but would not flash or light.

In Oklahoma[27] burning springs are found in several parts

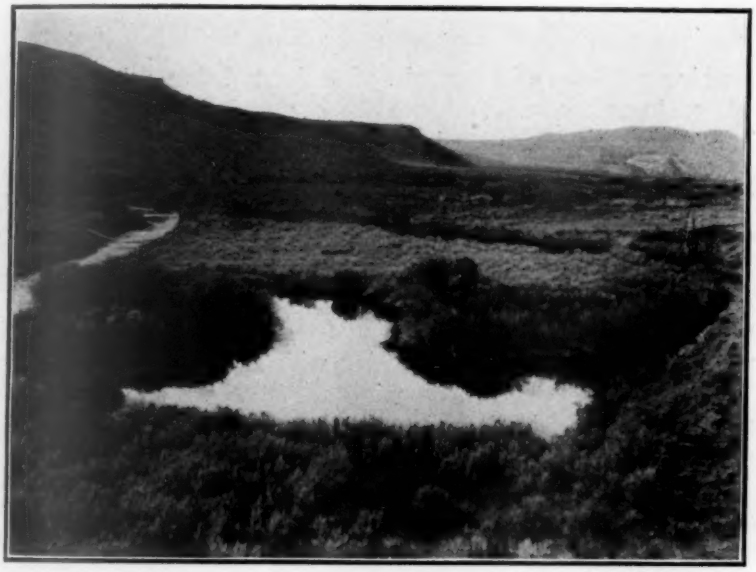
[26] Haworth in the University Geological Survey of Kansas, vol. i, p. 232. *Ibid.*, vol. ix, p. 25.

[27] Proceedings of the Natural Gas Association of America, vol. ii, p. 118.

of the State, the most notable being in northeastern Pittsburgh County, some twenty miles northeast of McAlester. At this point gas escapes over an area of perhaps 300 square feet. It issues from crevices in the soil and among the rocks, and when set on fire often continues burning for weeks.

In the summer of 1899 I visited the then territory of Wyoming[28] and saw many oil and gas springs. At Lander

FIG. 6.



View of the Little Pope Agie Valley, about ten miles southeast of Lander, Wyoming, in Twp. 32 N., R. 99 West.

I met an old-time trapper who had lived among the Shoshones. He told me that the Indians knew of many oil and gas springs, and called them "the place of the Big Medicine."

Fig. 6 is a view of the Valley of the Little Popo Agie.[29] At the right is a derrick over the No. 1 Murphy Well, said to

[28] Sixteenth Annual Report, U. S. Geol. Survey, part iv, p. 382. Annual Report Territorial Geologist, 1886, Laramie, Wyo. Annual Report Territorial Geologist, 1888, Cheyenne, Wyo. Bulletin 119, U. S. Geol. Survey, p. 64. University of Wyoming Bulletin No. 14, Oct., 1893, p. 161. University of Wyoming Bulletin, No. 2, Petrol. Series, Jan., 1897.

[29] About 10 miles S. E. of Lander, in Twp. 32, N., R. 99 W.

be 300 feet deep. At this place the oil and gas still seeped from the ground, as well as leaked from the well.

About 1833 Captain Bonneville[30] "made search for the great tar springs, one of the wonders of the mountains, the medical properties of which he had heard extravagantly lauded by the trappers." His description points to this place, and when they found it "the men immediately hastened to collect a quantity of it to use as an ointment for the galled backs of their horses and as a balsam for their own pains and aches."

A cut-off had been dug across the original bend of the river, as seen to the left of the view, and dams put in, thus forming a U-shaped reservoir. I estimated that this contained 18,000 barrels of oil and was the accumulation of nine years' leakage around No. 1 well.

This oil made a great trap for ducks, geese, and other birds, for if they lit on its surface they could not rise again out of the thick oil; also, many sheep were lost in it. Before, and for a time after, the advent of the Union Pacific, oil from this place found profitable sale for lubricating purposes to the railroad, ranchers and mills, but eventually practically all this trade was lost through competition with Eastern refined oils.

An oil sand is shown cropping out in Fig. 7 above the man, and in front of him is a deposit made by oil seepage. At the foot of the slope was a strong gas escapement.[31]

In the early days of California[32] the Catholic fathers utilized asphaltum for roofing their missions and other buildings from nearby deposits, and from time immemorial the Indians had known of and used this mineral.

The first discovery of bitumen at Summerland,[33] California, was where there was a fumarole, some twenty feet in diameter, from which warm carburetted and sulphuretted hydrogen gas escaped. No vegetation grew on this place. The Spaniards had a legend that a man was killed there, which, according to them, accounted for the fact that nothing grew there.

A pipe driven in this spring and reduced to two inches

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[30] Washington Irving's "Bonneville," p. 142.

[31] In Fremont County, Wyoming, about forty miles due east of Lander.

[32] "Petroleum in California," by Redpath.

[33] Bulletin No. 16, State Mining Bureau, 1899, p. 62.

gave pressure and quantity enough of gas to make a flame ten feet long. The following up of this discovery led to drilling submarine oil wells from a wharf. Cooper says:[34] "Frequently gases are seen to ascend from the bottom of streams and pools of water, and that it occurs in many places in California."

I have shown a wide geographic distribution of bitumen, and particularly of natural gas. It is one of the most difficult

FIG. 7.

Fremont County, Wyoming, about 40 miles due east of Lander. Oil sand croppings and hardened oil made by seepage.

facts of history to understand the extreme slowness with which the human race developed the industrial use of bitumens, especially that of oil and gas. It is only about thirty years since natural gas began to come in use on a large commercial scale.

Time forbids that I should dwell longer on the history and surface indications of bitumens, so I will pass to the next part of my subject.

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[34] Bulletin No. 16, State Mining Bureau, 1899, p. 83. See Bulletin No. 321, U. S. Geol. Survey, part i, p. 11 and quotation bottom page 13.

SECTION II.

ORIGIN OF BITUMENS.

Many theories have been put forward to account for the origin of bitumens in the crust of the earth. There are two main groups of these hypotheses, one ascribing an inorganic and the other an organic origin.

The celebrated chemists[35] Bertholet and Mendeljiff pointed out (in 1869 and 1877) possible chemical reactions under which hydrocarbon compounds could be generated in the earth's interior. Some advocate a volcanic origin[36] of natural gas and petroleum, and give examples of hydrocarbons in ancient plutonic rocks as well as in present volcanoes.

The organic[37] hypothesis can be backed by more familiar facts than those just outlined.

Natural gas and other bitumens are combustible substances, and every other substance that we know in Nature that can be burned is organic in origin.

Chemists have produced unmistakable members of the petroleum group, including illuminating oil, lubricating oil, benzine, and paraffin, from the distillation of fish oil, and in such distillations some gas is given off.

By observation[38] we know that natural or marsh gas is a product of slow primary decomposition at low temperature of organic matter contained in sediments, and so is from an organic source. These decompositions were extremely slow, and the present pools of oil and gas are the accumulation of enormously long periods of time.

I think it is safe to say, from our present knowledge, that some bitumens may come from an inorganic source, but by far the greater amount come from terrestrial and marine vegetation and organisms.

We might well adopt for our conclusions the translation of an inscription placed over a meteorite that fell centuries ago in Germany: "Many men say many things; every one says something; nobody gives a satisfactory account."

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[35] Tenth Census, vol. x, p. 59.

[36] *Journal Can. Min. Inst.*, vol. iii, pp. 68-89.

[37] Adapted from Dr. Orton, *Bulletin N. Y. State Museum*, vol. 6, No. 30, p. 426.

[38] U. S. Geol. Survey, Eleventh Ann. Rep., part 1, p. 613.

SECTION III.

THE GEOLOGY OF BITUMEN.

With Especial Reference to Natural Gas.

In the gaseous, liquid, and solid forms bitumen is one of the most widely distributed of substances. Its geological limits of profitable production include the whole range of unaltered strata, from the Cambrian rocks to the most recent series of the Quarternary system.

The publications of the United States Geological Survey, with those of the several States, and of the geological societies, give a wealth of detail of the geology of every locality in the United States where oil and gas are now produced in paying quantity. These works should be consulted on geological questions. Many of them can be had for the asking, and for those that are sold the price only covers the cost of printing and mailing.

Geology is more of a historic than exact science, with but few demonstrations of the sort that carry mathematical certainty, and the wise geologist confines his teachings to the known, without attempting the rôle of a prophet.

The principles [39] of geology are not visionary; they are supported by a great multitude of harmonized facts. The maps and sections in the publications mentioned show this to be the case. But the geologist does not know whether a sand [40] exists at a given spot beneath the surface, nor whether, if there be a sand, it holds gas or not, nor whether, if the gas be there, it will flow toward a drill hole. But this ignorance of facts, all of them out of sight and out of reach before experiment, he shares with everybody else. No one, absolutely no one, can know such facts before a well is bored.

Rocks are of many kinds, and as the paying pools of gas are found only in those of sedimentary origin, I will refer to this kind only.

Such rocks are composed of the detritus of older rocks and carried by water, air, and ice in motion into lakes and seas,

[39] Adapted from J. P. Lesley's letter of transmission, Penna., Second Geological Survey, vol. iii.

[40] Sand is a general term, and includes sandstone and limestones that carry oil or gas in paying quantity.

forming gravels, sands, and clays which are later consolidated into conglomerates, sandstones, and shales.

In smaller portion the materials are also carried in solution, and the deposits are then called organic, if formed with the aid of life, and chemical without this aid. Organic and chemical rocks are limestones, cherts, gypsums, peat, lignite, and coal.

Much terrestrial and marine vegetation with marine, brackish, or fresh-water organisms is thrown down with such deposits, forming, in the aggregate, a vast amount of carbonaceous material sufficient to account for all the gas and other bitumens found in Nature.

These sedimentary rocks are mostly deposited in layers or beds originally in a horizontal position, or nearly so, and which can easily be separated. These layers are called strata, and the deposits are said to be stratified.

Most of such rocks grew up in the sea, some cover thousands of square miles, and for the accumulation and growth of these enormous deposits vast periods of time were required.

All stratified rocks can be divided into two general divisions with reference to their porosity—the permeable and the impermeable. Some rocks are freely permeable, others are less so, and still others resist the passage of water so effectually that we call them impermeable.

Conglomerates and sandstones are types of the porous group. Shales and clays represent the impervious series, and are perfect seals when they carry moisture.

Dolomitic and crinoidal limestones, under certain conditions, are also porous, but most of the limestones are impervious.

The porous rocks usually contain water, and when near the surface it is fresh. Sometimes they are dry, or they contain gas only, or they contain oil and gas, or they contain oil, gas, and water, and such rocks are referred to as reservoir rocks, and I will describe them more particularly later.

When water is associated with oil or gas or nearby strata below or above them, it is invariably impregnated with salt or sulphur, or both. Outside of oil and gas territory, potable water may be got at considerable depth, as at Charleston, S. C., where warm potable water (99½° F.) is obtained between 1,950 and 2,000 feet.

Porous rocks, which have become a reservoir particularly

of oil or gas, have so become by virtue of the fact that its contents are confined within it by an impervious covering which generally consists of shale or clay carrying some moisture.

By orogenic movements the stratified rocks have been arched up, thrown into waves and crumpled. The crystallization of salt[41] from solution and intrusion of laccoliths has in a few places raised up dome-shaped hills of these rocks, and volcanic plugs and vents have been forced up through them. Such disturbances of original structure have formed anticlinals, synclinals, domes, fault, joint cracks, and volcanic vents, and these variations play an important part in the accumulation and concentration of oil and gas into paying "fields" or "pools."

The fundamental geologic conditions necessary for a profitable accumulation of oil or gas must be:

First. A source of supply, probably from carbonaceous material enclosed in sedimentary strata.

Second. A reservoir rock such as may be found in any porous rock that will allow the passage of fluids between its particles.

Third. A cover of impervious moisture holding rocks to seal and hold the oil and gas from loss by dissipation.

SECTION IV.

CLASSIFICATION OF OIL AND GAS ACCUMULATIONS.[42]

I. Where anticlinal and synclinal structure exists.

(*a*) Strong anticlines standing alone.
(*b*) Well-defined anticlines and synclines alternating.
(*c*) Monoclinal dips.
(*d*) Terrace structures.
(*e*) Broad geanticlinal folds.
(*f*) Overturned folds.

II. Without anticlinal structure.

(*a*) Lenticular sandstones enclosed in shale.

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[41] G. D. Harris in Bulletin No. 429, U. S. Geological Survey, p. 8.
[42] "Economic Geology," by F. G. Clapp, vol. v, No. 6, pp. 503–521.

(*b*) Sandstones that shade into shale.

Both (*a*) and (*b*) are entirely enclosed in shale and not in communication with water under hydrostatic pressure.

III. Domes, or quaquaversal structures.
IV. Sealed faults.
V. Oil and gas sealed in by asphaltic deposits.
VI. Contact of sedimentary and crystalline rocks.
VII. Joint cracks.
VIII. Surrounding volcanic vents.

The great gas fields come under the first two classes of accumulations, and as the gas associated with the other classes is not of commercial importance I will not refer further to them.

Through the investigations of geologists [43] working in the great Appalachian field the structural or anticlinal theory of the accumulation of oil and gas was evolved.

The three fundamental geologic conditions for the accumulation of oil and gas have been previously stated. In addition to these, for the proper theoretical anticlinal conditions we should have:

Fourth. Water in the porous stratum with the oil and gas.

Fifth. Geologic structure, or a decided slope of the porous stratum.

It cannot be doubted that the fifth condition mentioned,—geologic structure—does play an important part in the accumulation of oil, and particularly of gas, and it is a fact that many gas pools are located along anticlinals and in domes, but the theory is not, in my opinion, of universal application.

To such fields as the theory applies [44] it is of economic importance, and the geologist should be consulted to locate favorable points in advance of any drilling.

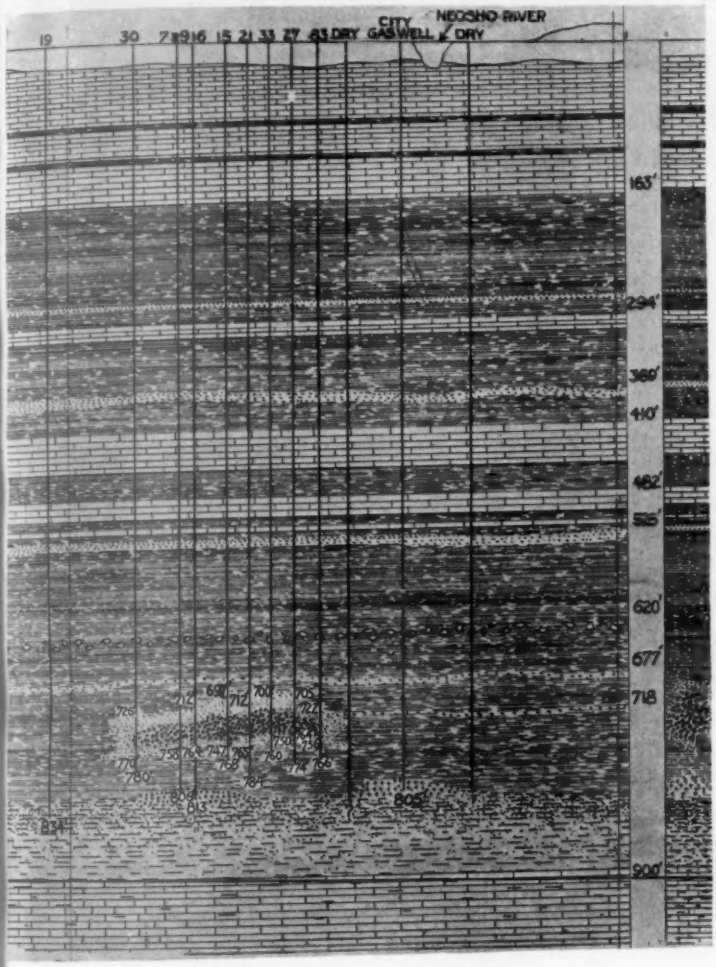
Fig. 8 is a well section across the oil and gas trend just east of Chanute, Kansas. The productive oil sand shown at this point is about one-third of a mile wide and 20 to 30 feet

[43] See "History of the Structural or Anticlinal Theory," by I. C. White, West Virginia Geol. Survey, vol. i (a), 1904, p. 48.

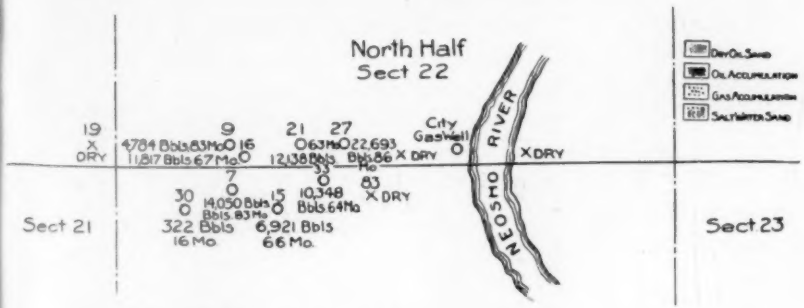
[44] West Virginia Geol. Survey, vol. i, p. 60.

FIG. 8.

Plan and section of wells drilled by I. N. Knapp, one mile east of Chanute, Kansas, showing average width of productive oil sand from east to west, total length about three miles north and south. Small spots of gas sand under soil.



20' Soil
57' Limestone
5' Black Shale
32' Limestone
5' Black Shale
44' Limestone
108' Shale
5' White Sand
18' White Shale
15' Limestone
60' Shale
10' Sand (Gas and Salt Water
31' Shale
40' Limestone
32' Shale (Water)
23' Limestone
10 Black Shale
5' Limestone
5' Shale
10' Sand
80' White Shale
5' Black Shale
18' Shale and Shells
10' Dark Shale
20' White Shale
2' Sand
29' Black Shale
10' Sandy Shale
Dark Shales
Sea Level
Boone Limestone
or
Mississippi Rock



thick. The real productive sand is from 10 to 15 feet thick and 700 to 750 feet deep in the level lands along the Neosho River. It varies in width from one-fourth to one-half a mile, and is about five miles long, along the strike of the dip, and practically exactly horizontal in width and length. It is, therefore, not a continuous sheet of sandstone like the Pennsylvania oil sands or Trenton rock. It carries nothing but oil, and does not connect at any place with water-bearing strata, but grades into impervious shales in all directions. The oil is combined with but little gas, and wells will not flow unless drilled deep enough to prick the gas sand if found below.

It is evident that the anticlinal theory played no part in the accumulation of oil in this particular sand.

Below the oil horizon, some thirty to forty feet, and just on top of the salt-water sand, is a gas horizon with occasional spots productive of gas. The southernmost well that I drilled in this trend proved to be a gasser at 781 feet, and the northernmost well, three miles away, a gasser at 780 feet, the tops of the wells being probably within five feet of the same elevation. The gas sands here appear like small sand bars or sand dunes laid down on top of the salt-water sand, which were covered up by mud (the shales) and in time cemented into the rock we find. The gas sand (cuttings from the gas-bearing sandstone) and the salt-water sand (cuttings from the salt-water sand rock) are quite different in appearance. The salt-water sand carries minute particles of mica that are characteristic, and as soon as they appear in the cuttings, even before salt water shows, it is at once recognized that no gas will be obtained at that particular point.

At Altoona, Kansas, my drilling developed gas in two sands having the same relative position as the oil and gas sand at Chanute.

The conclusion is that each oil and gas field must be considered by itself, both from a geologic and operating standpoint. The geologist, operator, or driller expert in one field has to learn the business over again when he goes into a new field.

When a man starts as pioneer in a new field in which practically nothing is known of its geology, with no well records or methods of operating work out, he is up against a pretty hard proposition.

SECTION V.

RESERVOIR ROCKS.

The porosity of rocks,[45] sand, and earth has been the subject of elaborate investigation as to their capacity to hold water, and the rate of flow of water and air through them. It has been shown that if a theoretical sand consisted of perfect spheres of equal diameter, placed at a maximum distance apart, the pore space is 47.64 per cent.; if at a minimum, 25.95 per cent. These percentages hold true, no matter what the diameter is. This proves the pore space is the same in a fine sand as in a coarse one.

If a quantity of common shot be poured in a glass and the open spaces filled with water, the porosity will be found well within the limits given, whether the shot be fine or coarse, and the same is true of common sand.

After the sands of the sandstones were laid down they have been subject to "secondary growth" by the slow deposition of cementing material from circulation of underground waters, thus forming rock and reducing the original porosity in varying degree. The porosity of limestones has also been decreased in similar ways and also increased by solution.

The fractional part of a rock in which there are open spaces or voids determines its porosity. That is, if a cubic foot of rock will hold, when saturated, one-tenth of a cubic foot of oil or water, such rock is said to have a porosity of 10 per cent., for one-tenth of its volume is pore space. If such pore space was filled with gas at 30 atmospheres, then each cubic foot of rock would hold 3 cubic feet of gas at atmospheric pressure.

All rocks are porous in some degree. Even slate of the closest grain will hold some liquid in its microscopic cavities. Those rocks that are so open-grained or porous that, if a hole be drilled into them, they can be drained of their liquid or gaseous contents are called reservoir rocks.

The porosity of the reservoir rocks often extends to great distances. Striking proof of this is supplied in the practical development of many gas fields. In northwestern Ohio,[46]

[45] See papers of F. H. King and C. S. Slichter, Nineteenth Annual Report, Geol. Survey, part ii, 1897–1898.

[46] Geological Survey of Ohio, 1890, p. 88.

according to Dr. Orton, wells separated by intervals of a half or three-quarters of a mile are found to affect each other's flow and pressure to an important degree, and it is also found that areas of several consecutive square miles can sometimes be drained of their gas by a single well.

Underground[47] water may be found in cracks and crevices in rocks, but by far the larger portion exists in the minute pores and openings between the rock particles themselves.

Caves, cracks, or crevices in rock are largely surface phenomena. Below the surface, as the depth increases, the weight of the superincumbent material tends to close any opening, and Professor Van Hise[48] shows that at a depth of about six miles the weight is so great that all rocks become plastic and flow so as to close up even their minute microscopic pores.

A West Virginia well[49] developed gas in the Gantz sand horizon at 2,770 feet, as well as in the "Fifty-foot" sand at 2,840 feet, and a still larger flow was found in the fifth or McDonald sand at 3,115 feet, the hole being completed at 3,300 feet. The Gantz and "Fifty-foot" sands constituted one solid, coarse, pebbly rock, and in order to save all of the gas flows the well was packed in the upper portion of this pebbly stratum. From the great depth of the well it was expected that the rock pressure would rise until it exceeded 1,500 pounds to the square inch, but when shut in the gauge, which began to register rapidly at first, very soon slowed up, and finally stopped at 650 pounds. As the pressure did not rise sufficiently rapid to correspond to the apparent volume of the gas when the gate valve was open, it was concluded that a large portion of the gas was being forced into the porous Gantz and "Fifty-foot" beds and stored therein, the 650 pounds representing the pressure necessary to store in the pores of that rock all the surplus gas produced from the three horizons at that pressure.

(*To be continued.*)

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[47] See U. S. Geological Survey Water Supply and Irrig., Paper No. 67, pp. 14–16.

[48] See paper of C. R. Van Hise, Sixteenth Annual Report, U. S. Geol. Survey, part i, 1896, p. 593.

[49] West Va. Geol. Survey, vol. i (a), p. 7. Alonzo Edwards Well No. 1, near Wadestown, Monongalia Co., W. Va.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

WALTER V. TURNER,

Chief Engineer Westinghouse Air Brake Co., Pittsburgh, Member of the Institute.

AND

P. H. DONOVAN,

Mechanical Engineer, Westinghouse Air Brake Co., Pittsburgh

THE air-brake equipment for steam road cars hereinafter described is the outcome of a close acquaintance with and a careful study of the present-day requirements of steam road service, which brings a realization of the present limitations of the air-brake equipment.

There has been such marked improvement in the design and construction of railway motive power and rolling stock during late years that the best possible air-brake equipment should be considered none too good.

The demonstration train (Fig. 28) which the Santa Fe Railroad Company hauled over its lines some months ago for educative purposes clearly illustrates this wonderful advancement.

The train was composed of two locomotives, and two each of the various types of cars for both freight and passenger service, one of each being built in 1881, and the other in 1911. The locomotive, no doubt, shows the most wonderful development. The No. 0–48, built in 1881, weighs 133,000 pounds and has a drawbar pull of 14,000 pounds, as against 850,000 pounds weight and a drawbar pull of 110,000 pounds for locomotive No. 3009, built in 1911. This large locomotive is able to draw much heavier and longer trains, and consequently the time element in the application of the brakes between the first car and the last will be increased accordingly, with a corresponding increase in the possibilities of damage, due to slack running in or out. The smokers and coaches also show a great increase

[1] Concluded from page 464.

in size and capacity, the older smoker having a weight of 49,400 pounds and a capacity of 28 passengers as against 119,100 pounds weight and 86 passengers with the latest type. The coach of 1881 has a weight of 50,300 pounds with a capacity of 48 passengers, while the modern coach seats 75 passengers and weighs 123,100 pounds.

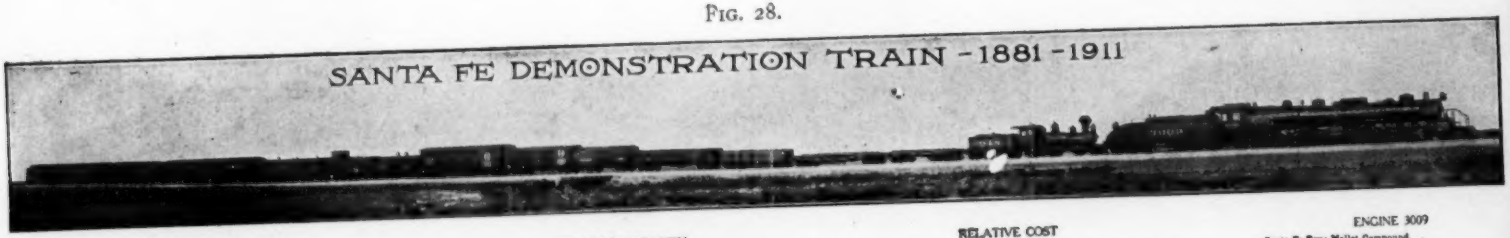
Natural improvement, combined with the effort of railroad companies to attract business by superior equipment, and the demand of the travelling public for greater comfort when travelling, shorter schedules (higher speeds), and, at the same time, greater safety, has led to the development of heavier rolling stock. These cars and locomotives are of such weight that they cannot be as efficiently braked with the older type of air-brake equipment as could the rolling stock of years gone by; and this is particularly true of emergency applications, as because of the very high speeds attained and the large cylinders necessarily employed the time element in the attainment of cylinder pressure, and the lowered brake-shoe friction (by reason of the tremendous energy per brake shoe to be dissipated), means that the stopping distance, with the brake equipment remaining the same as with the rolling stock of previous years, is lengthened out several hundred feet. Obviously, therefore, if equal safety is to be maintained and the schedules operated profitably, at least as high (relative) a rate of retardation must be provided as heretofore.

It has already been pointed out that actuating the brakes electrically results merely in the elimination of the time element of application, the retarding force coming solely from the pneumatic operation, and that adding electric control without first developing the pneumatic features to a high degree is an expensive way of seeking improvement.

Not only this, but the heavier vehicles and lengthened trains have vastly increased the energy to be controlled and magnified the time element necessarily involved in so doing it. It is imperative that if the same relative freedom from surges, shocks, and stresses is to be retained, the brake control must be much more flexible and responsive than has heretofore been the case.

With this end in view, great improvements have been made in the purely pneumatic brake, but full attainment is only possible when the pneumatic brake is operated electrically, as by

FIG. 28.



RELATIVE WEIGHT

	OLD EQUIPMENT	NEW EQUIPMENT
Locomotive	122,000 pounds	850,000 pounds
Flat car	19,200 pounds	32,100 pounds
Coal car	21,000 pounds	36,800 pounds
Stock car	26,000 pounds	46,200 pounds
Box car	27,600 pounds	46,900 pounds
Way car	23,800 pounds	36,000 pounds
Smoker	49,400 pounds	119,100 pounds
Coach	51,300 pounds	133,100 pounds

RELATIVE CAPACITY

	OLD EQUIPMENT.	NEW EQUIPMENT.
Locomotive	14,000 pounds drawbar pull	110,000 pounds drawbar pull
Flat car	40,000 pounds	80,000 pounds
Coal car	50,000 pounds	80,000 pounds
Stock car	40,000 pounds	80,000 pounds
Box car	40,000 pounds	80,000 pounds
Smoker	28 passengers	96 passengers
Coach	48 passengers	75 passengers

RELATIVE COST

	OLD EQUIPMENT.	NEW EQUIPMENT
Locomotive	$7,740.00	$42,860.00
Flat car	260.00	943.00
Coal car	338.00	1,096.00
Stock car	450.00	1,402.00
Box car	475.00	1,305.00
Way car	420.00	1,383.00
Smoker	3,000.00	12,124.00
Coach	3,000.00	12,820.00

ENGINE 3009

Santa Fe Type Mallet Compound.
Largest Locomotive in the World.
Built at Topeka Shops, 1911.
Length 130 feet 7½ inches.
Cylinders 28 In. x 30 In. x 32 In stroke.
Steam pressure 225 pounds.
Capacity of tender 12,000 Gals. Water,
4,000 Gals. Fuel Oil.

OLDEST TRAIN CREW

E. B. Sill, Conductor, 33 Years' Service.
Peter Teltin, Engineer, 39 Years' Service.

this means the time element between the first and rear of train is reduced, and the degree of retardation best suited to speed can be measured to a degree.

As intimated in the commencement of the paper, this has long been known, for it is obvious that with any class of rolling stock or make-up of train the elimination of the time element of brake operation will be both an improvement in this respect and also in the degree of perfection required in the human agents in its manipulation.

Coincident, however, with the other advancements, electric lighting of trains coming into existence, and its almost universal use on trains of such car equipment, has given an opportunity of an electric pneumatic system of brakes for the control of even "steam road" trains.

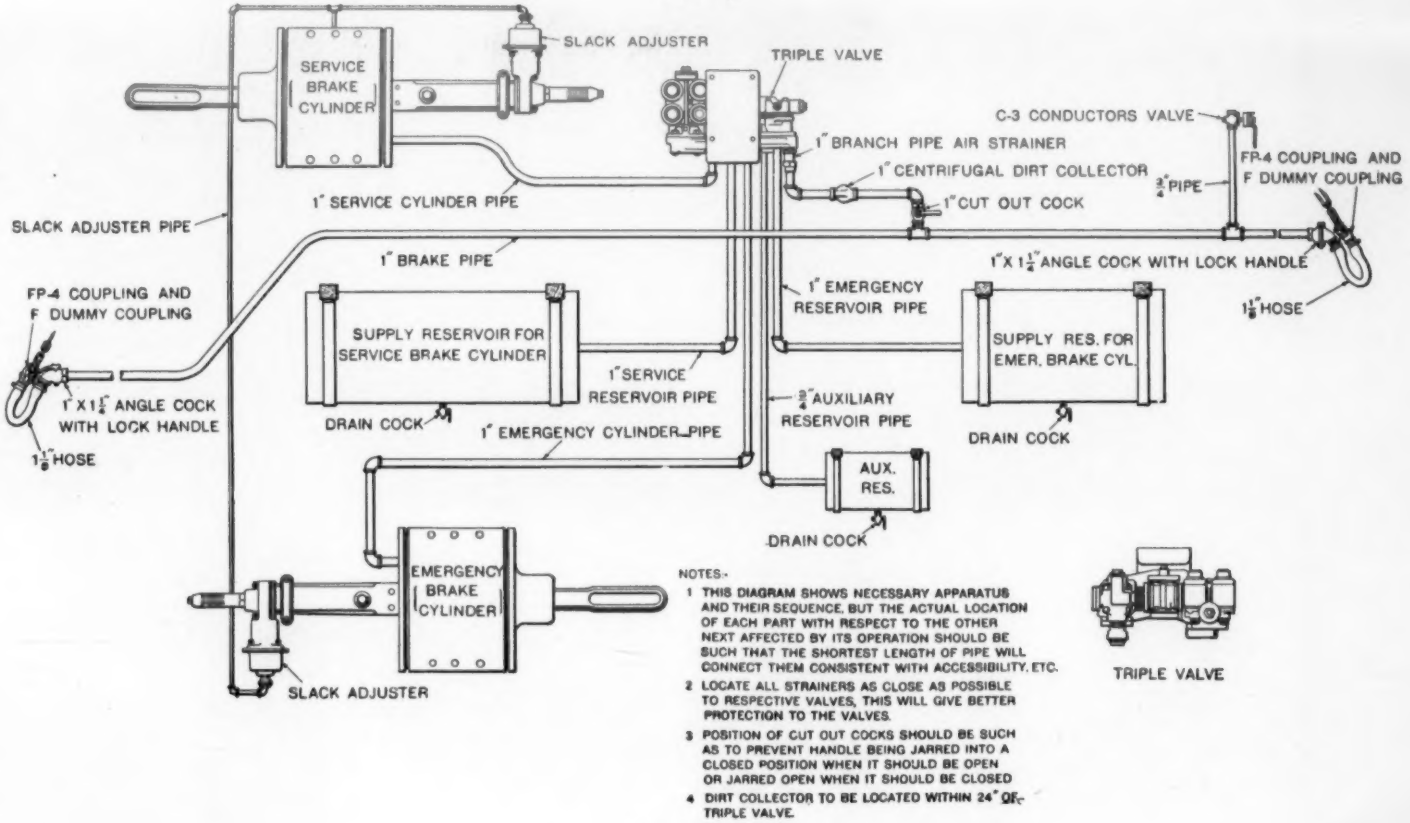
Therefore the pneumatic brake portion of the equipment hereinafter described is of the highest type yet designed for steam road service, and has electric control for both service and emergency operations. It has all the important features necessary for a very efficient pneumatic brake, as enumerated in connection with the previously-described equipment, with the addition of others which are necessary in order that the heavy trains in steam road service may be braked, conformable to reasonable requirements.

Two brake cylinders are used, one for service application and both for emergency. A low total leverage is possible (resulting in greatly-increased overall efficiency and economy of locomotive power) since the braking power is based on an equalization pressure of 86 pounds instead of 50 pounds as with former equipments.

Fig. 29 shows the piping diagram of this equipment, which pneumatically consists of a control valve; auxiliary, service and emergency reservoirs; and service and emergency brake cylinders. The auxiliary and service reservoirs combined form the reservoir volume for the service brake cylinder, and are so connected that when recharging the equipment (graduated release feature cut out), after a brake application, the service reservoir is temporarily cut off from the source of air supply and only the small auxiliary reservoir volume is added to the brake pipe, which reduces to a minimum the amount of air required to release all the brakes in the train. After the brake-

FIG. 29.

FIG. 29.

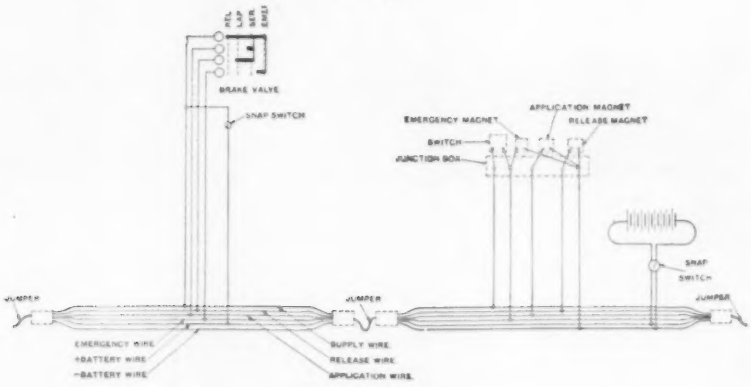

SERVICE BRAKE CYLINDER
SLACK ADJUSTER
TRIPLE VALVE
C-3 CONDUCTORS VALVE
1" BRANCH PIPE AIR STRAINER
1" CENTRIFUGAL DIRT COLLECTOR
1" CUT OUT COCK
3/4" PIPE
FP-4 COUPLING AND F DUMMY COUPLING
1" SERVICE CYLINDER PIPE
SLACK ADJUSTER PIPE
1" BRAKE PIPE
1" X 1 1/4" ANGLE COCK WITH LOCK HANDLE
1 1/8" HOSE
FP-4 COUPLING AND F DUMMY COUPLING
1" EMERGENCY RESERVOIR PIPE
SUPPLY RESERVOIR FOR SERVICE BRAKE CYLINDER
SUPPLY RES. FOR EMER. BRAKE CYL.
1" SERVICE RESERVOIR PIPE
3/4" AUXILIARY RESERVOIR PIPE
1" X 1 1/4" ANGLE COCK WITH LOCK HANDLE
1 1/8" HOSE
DRAIN COCK
DRAIN COCK
1" EMERGENCY CYLINDER PIPE
AUX. RES.
DRAIN COCK
EMERGENCY BRAKE CYLINDER
SLACK ADJUSTER
NOTES:-
1 THIS DIAGRAM SHOWS NECESSARY APPARATUS AND THEIR SEQUENCE, BUT THE ACTUAL LOCATION OF EACH PART WITH RESPECT TO THE OTHER NEXT AFFECTED BY ITS OPERATION SHOULD BE SUCH THAT THE SHORTEST LENGTH OF PIPE WILL CONNECT THEM CONSISTENT WITH ACCESSIBILITY, ETC.
2 LOCATE ALL STRAINERS AS CLOSE AS POSSIBLE TO RESPECTIVE VALVES, THIS WILL GIVE BETTER PROTECTION TO THE VALVES.
3 POSITION OF CUT OUT COCKS SHOULD BE SUCH AS TO PREVENT HANDLE BEING JARRED INTO A CLOSED POSITION WHEN IT SHOULD BE OPEN OR JARRED OPEN WHEN IT SHOULD BE CLOSED
4 DIRT COLLECTOR TO BE LOCATED WITHIN 24" OF TRIPLE VALVE.
TRIPLE VALVE

Piping Diagram.

pipe and auxiliary reservoir pressure has increased to within five pounds of the maximum pressure carried in the system or within five pounds of the pressure in the emergency reservoir, the service reservoir is automatically cut in and will then charge to the same pressure as that to which the system is limited.

The dividing of the auxiliary reservoir volume into two volumes permits of a very flexible graduated release with a minimum emergency reservoir volume, as the graduated release feature is controlled by the emergency reservoir air expanding into the auxiliary reservoir volume; also to have a smaller volume

FIG. 30.



Wiring Diagram.

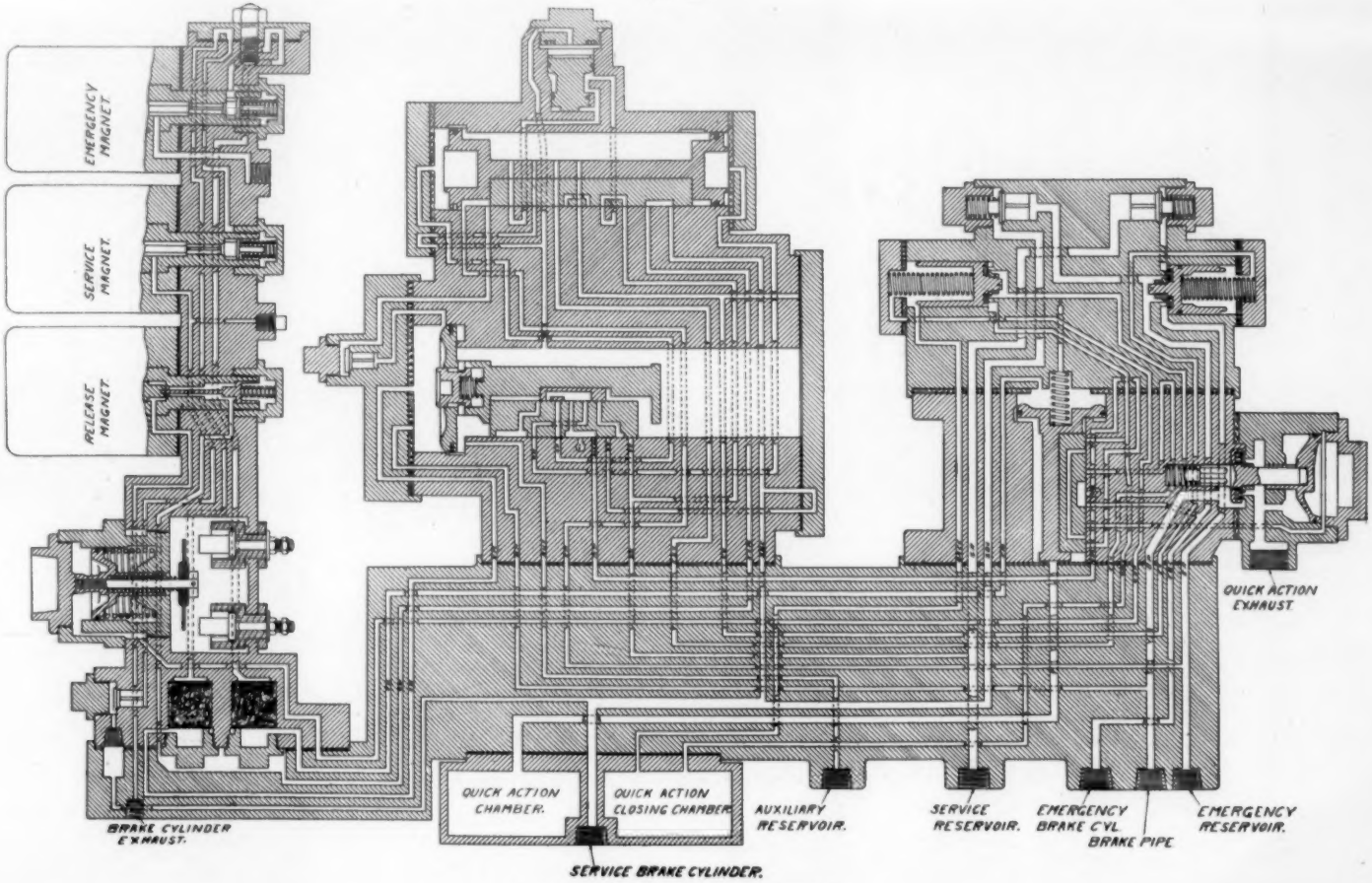
for the emergency reservoir to equalize with in graduated release operation, thereby making this feature more positive than heretofore, as with the older types of brake.

The emergency reservoir, besides being used in obtaining the graduated release, equalizes with the emergency brake cylinder in an emergency application of the brake.

Fig. 30 shows the wiring diagram. Electrically the equipment comprises the usual application and release magnets, with their attached valves controlling electric service application and release of the brakes, and also the emergency application magnet with its valve, which controls the operation of the emergency parts of the control valve. The emergency switch is used to close the emergency magnet circuit and thus cause the electro-pneumatic emergency, whenever there is a very sudden reduction

FIG. 31.

FIG. 31.



Control Valve, Diagrammatic Assembly.

in brake-pipe pressure, such as when a hose bursts or separates.

Fig. 31 shows the control valve, which is comprised of three general portions, viz., equalizing, magnet, and emergency portions, and a three-faced pipe bracket for these portions, as shown on the diagrammatic drawing.

The *equalizing portion* (central part of figure) is similar to a plain triple valve and controls the application of the service brake and, by means of the release piston and valve, the graduated release and the release of the service cylinder pressure.

The *magnet portion* (left-hand part of figure) is composed of three magnets and their valves and also the emergency switch. These magnets are the service, emergency, and release magnets, and control the electro-pneumatic operations which their names imply. The emergency switch is used to close the emergency magnet line circuit and thus cause electro-pneumatic emergency whenever there is a very sudden reduction in brake-pipe pressure, such as when a hose bursts or separates.

The *emergency portion* (right-hand part of figure) controls the pneumatic emergency, the connecting of the emergency reservoir and cylinder, and also embodies the protection valve, which causes quick action whenever the brake-pipe reduction is carried below a certain predetermined point; the two check valves which allow the two reservoirs and cylinders to finally equalize in an emergency application are also located in this portion.

OPERATION OF THE ELECTRO-PNEUMATIC CONTROL VALVE FOR STEAM ROAD SERVICE.

Charging the System.

Air from the brake-pipe enters the control valve at connection marked " Brake Pipe " and flows to the under side of the quick-action valve, forcing same to its seat, also to the under side of the protection valve, which remains seated until a certain predetermined pressure is obtained, when it will move very quickly and seat toward the left, owing to its left side being connected to the quick-action closing chamber, which, under these conditions, is open to the atmosphere by means of the quick-action piston and emergency switch port.

Brake-pipe air flowing to the under side of the protection

valve can also flow through the small choke into the emergency slide-valve piston cylinder, and force same to the release position: this air can flow through the emergency piston feed groove and charge the quick-action chamber.

With the emergency slide valve in release position, the emergency brake cylinder is open to the atmosphere, through the exhaust cavity in the face of this valve.

After the protection valve lifts and separates the quick-action closing chamber vent and quick-action piston ports, the brake-pipe air can flow through the quick-action closing chamber charging port, charging this chamber at the same time as the brake pipe.

Brake-pipe air can also flow to the face of equalizing piston, forcing same to its release position, and charging through the feed groove into the equalizing slide-valve chamber and the auxiliary reservoir.

Air in the equalizing piston cylinder can also raise the emergency reservoir charging check valve, and flow past same to the release slide-valve chamber and thence to the emergency reservoir, and since this and the equalizing slide-valve chambers are connected, the auxiliary and emergency reservoirs will charge at one and the same time from zero pounds pressure. The equalizing slide-valve chamber is also connected to the top of the charging valve, forcing it downward against its stop, and thus opening the service reservoir charging port, which leads through the release slide valve and piston to the under side, as well as the side of the charging valve, to the service reservoir port—the latter port passing through and being controlled by the release slide valve. In this position the small end of the release piston is open to the atmosphere through the equalizing slide and graduating valves, consequently the release piston will be held in release position.

The release slide-valve chamber is open through the emergency valve port to the top of the emergency valve, and the emergency reservoir air is in communication with its under side, hence this valve is balanced and is held seated by its spring. Emergency reservoir air is also present on top of the emergency reservoir check valve and the service reservoir air is in communication with its under side: this valve permits these two volumes to be connected in an emergency application.

With the release slide valve in release position, the service brake cylinder is open to the atmosphere through the release slide-valve cavity and the release magnet.

Brake-pipe air entering the equalizing piston cylinder will also flow through the service magnet port and strainer to the top of the service magnet valve; and the brake-pipe air in the emergency piston cylinder will also flow through the emergency magnet port and strainer to the top of the emergency magnet valve.

In release position the tops of the emergency switch, protection valve, and quick-action piston are connected to the atmosphere by means of a small drilled hole in the latter and the quick-action exhaust.

ELECTRIC SERVICE APPLICATION.

When an electric service application of the brakes is desired, the brake-valve handle is moved to the service application position, which is the same for both electric and pneumatic operation, in which the release magnet circuit is closed, energizing this magnet, which in turn seats its valve and closes the exhaust port from the service cylinder to the atmosphere. The service magnet circuit is also closed, energizing this magnet, which in turn opens its valve. This allows the brake-pipe air to flow from the equalizing piston cylinder past the service magnet check valve into the brake cylinder. This port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston and its slide valves to move toward their service application positions until the piston rests against its cylinder cap gasket; but this rate of reduction is not rapid enough to move the emergency piston and its slide valve, since under these conditions the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced, consequently a service application is the result.

The first movement of the equalizing piston and graduating valve toward service position closes the feed groove, the emergency reservoir charging port, and the release piston port; opens the service port and allows the graduating valve cavity to connect the application end of the release piston and also the

resistance-increasing cavity to atmospheric pressure, thus requiring a considerably greater differential in pressure than is needed with the type "P" triple valve for example, before the equalizing slide valve can be moved to service position. The object of this is two-fold: First, to reduce the sensitiveness of the valve sufficiently to prevent fluctuations in brake-pipe pressure, due to the feed valve or other causes, from producing undesired light service applications or brakes creeping on; second, to insure the making of such a brake-pipe reduction in applying the brakes that no trouble in releasing can result from inability to establish sufficient differential, as may be the case where the brakes will apply on a very light brake-pipe reduction.

This movement of the equalizing piston and graduating valve by connecting the application end of the release piston to the atmosphere causes same to move to application position in which the emergency reservoir charging, the service reservoir charging, the graduated release, the service reservoir, and the service cylinder exhaust ports are closed and the emergency valve port separated from the release slide-valve chamber and connected to the emergency valve exhaust port, which latter port is closed by the emergency slide valve.

The first movement of the equalizing piston and graduating valve toward release position, however, again exposes the friction-increasing cavity to auxiliary reservoir air. Thus the valve will be easier to release than to apply.

The further movement of the equalizing piston toward its service application position carries the equalizing slide valve to service position, in which the auxiliary reservoir air is free to flow past the end of the equalizing graduating valve through the service port into the service brake cylinder.

When the equalizing parts have moved to the service position, the equalizing slide valve has opened past its end the service reservoir port, so that the service and auxiliary reservoirs are connected, and the volume of these two reservoirs is such that from an initial pressure of 110 pounds, they will equalize with the service brake cylinder at 86 pounds.

The service port will remain open until the auxiliary and service reservoir pressure is reduced to a point slightly lower than that in the brake-pipe, when the equalizing piston and graduating valve will be moved back from service position until

the equalizing piston rests against the equalizing slide valve (to lap position) and close same.

The service magnet may be held energized, thus holding its valve open and allowing the brake-pipe and brake-cylinder pressure to equalize, or it may be energized for only a portion of the time necessary to cause a full (equalized) service application, and thus cause a partial application of the brake, after which the parts will be moved to the service lap position, as above mentioned.

This energizing of the service magnet may be repeated several times, each time causing a further increase in the brake-cylinder pressure, until the final equalization of the auxiliary and service reservoirs into the service brake cylinder has taken place.

ELECTRIC EMERGENCY APPLICATION.

When it becomes necessary to stop in the shortest possible time, the brake-valve handle is moved to the emergency position and allowed to remain there until the stop is made and the danger has passed.

In this position the emergency magnet circuit is closed, energizing this magnet, which in turn opens its valve and allows the emergency piston cylinder air to flow through the emergency magnet port to the atmosphere; the emergency exhaust port of the brake valve is also open, but since the electric current travels so much faster than the reduction of air pressures, it is the electrical emergency that controls and applies all the brakes in the train simultaneously. The emergency magnet port is of such size as to permit of a rate of reduction which will cause the emergency piston and its slide valve to move over to the emergency position instantly. The equalizing parts will assume the same positions and perform the same functions as in service.

With the emergency piston and slide valve in emergency position, quick-action chamber air flows to the faces of the quick-action and switch pistons, moving these pistons so as to open the quick-action valve and close the emergency switch.

The quick-action valve and the emergency switch will remain open and closed respectively until the quick-action chamber can drain to the atmosphere through the small drilled port in

the quick-action piston and the quick-action exhaust port, when they will be returned to their normal positions by their springs.

As previously stated, the release slide valve has the top of the emergency valve connected to the emergency valve exhaust, and this exhaust port is now open through the emergency slide valve to the atmosphere—thus emergency reservoir air, which is always under the outer area of the emergency valve, will lift same and flow into the emergency brake cylinder.

The first slight reduction in the emergency reservoir port will allow the emergency reservoir check valve to raise and connect the service and emergency reservoirs, and as soon as pressure builds up in the emergency brake cylinder, this air will lift the service brake cylinder check valve and allow the two cylinders to become connected. Thus the two reservoirs can equalize into the two cylinders in the shortest possible time.

With the emergency slide valve in the emergency position, the quick-action chamber exhaust port is open past the end of this slide valve through a port in the equalizing slide valve into the equalizing slide-valve chamber and the service reservoir. This port maintains the pressure in the emergency slide-valve chamber and holds this piston and slide valve in the emergency position.

ELECTRIC RELEASE AFTER A SERVICE APPLICATION.

When it is desired to release the brake electrically, the brake-valve handle is moved to the electric release position, in which the release magnet circuit is open, de-energizing this magnet and allowing its valve to open.

The brake-pipe port in the brake valve is also open and is restoring the air in the brake pipe to its initial pressure. This increase in the brake-pipe pressure forces the equalizing piston and its slide valve back to their release positions, in which the release end of the release piston is connected to the atmosphere and the port leading to the application end is closed by means of the equalizing slide and graduating valves, and, since the emergency reservoir is always connected to the release slide-valve chamber, the pressure in this chamber will force the release piston to the right and thus connect the service cylinder to the atmosphere, through the release magnet port and valve.

With the release and equalizing valves in release position,

the emergency and auxiliary reservoirs are again connected, thus giving the quick recharge of the auxiliary reservoir. The service reservoir charging port and the auxiliary reservoir port to top of charging valve are also open, so that when the air in the auxiliary and emergency reservoirs is nearly to initial pressure, this valve will move downward and open the service reservoir port and allow the latter to be charged to the initial pressure.

ELECTRIC RELEASE AFTER AN EMERGENCY APPLICATION.

After an emergency application, the equalizing, release, and emergency pistons and their respective slide valves will remain in their emergency positions until the brake-pipe pressure is restored, as will also the protection and emergency valves. Then, with the brake-pipe pressure gradually increasing, the protection valve and the emergency piston and slide valve will be the first to go to their normal (release) positions, then the equalizing and release pistons and their slide valves.

With the equalizing slide valve in release position, the quick-action chamber exhaust port is open to the atmosphere, and, with brake-pipe air on the face of the emergency piston, this piston and valve are moved to the release position, thus opening the emergency cylinder exhaust and closing the quick-action chamber exhaust.

The equalizing slide valve also has the release end of the release piston open to the atmosphere, and the application end port closed, so that the release slide valve is also returned to the release position, allowing the service cylinder air to exhaust to the atmosphere, and opening the various ports, as under electric release after a service application.

ELECTRIC GRADUATED RELEASE.

The release of the brake may be graduated electrically by moving the brake-valve handle between electric release and electric lap positions. The brake-pipe port is open in the first of these positions; therefore, all the moving parts of the equalizing portion of the valve will be moved to their release positions, but the release magnet valve will be opened and closed, thus controlling the release of the service cylinder air.

In the above operation the emergency reservoir, which still

has initial pressure, is connected to the auxiliary; the brake cylinder pressure will be reduced a few pounds at each graduation; but the exhaust port stays open only until the auxiliary reservoir pressure is slightly higher than that in the brake pipe, when the pressure in the former will move the equalizing piston and graduating valve back from their release position to graduated release lap position, when the release end of release piston port is lapped, and the application end of the release piston port is opened to the atmosphere by the equalizing graduating valve. These ports opening and closing respectively, cause the release piston to move toward the right and cause its slide valve to close the service cylinder exhaust, when no further reduction in brake cylinder pressure can occur until the brake-pipe pressure is further increased, or leakage reduces the auxiliary reservoir pressure, when the above operation will be repeated.

PNEUMATIC OPERATION.

The brake valves used with this equipment have the same position for either electric or pneumatic applications; the brake valve is provided with an equalizing reservoir and piston similar in all respects to those of any automatic brake valve. Thus, should the rate of brake-pipe reduction made by the service magnet valves not be as rapid as the reduction of the equalizing reservoir through the preliminary exhaust port, the equalizing piston will lift, opening the equalizing discharge valve, and bring the rate of reduction up to the required amount. This feature is also a telltale, and should warn the operator of any inoperative magnets. For example, in case the electrical features of the control valve or of the entire train brake system should be rendered inoperative through the loss of current, breakdown, etc., the brakes can be operated pneumatically (and will so operate automatically, whether the operator is aware of the fact or not). For example, should one service magnet in a train become inoperative (unknown to the motorman), the brake-pipe reduction made by the magnet valves that are operative will cause the control valve with the defective service magnet to operate pneumatically.

Similarly, should the electric control of the entire brake system fail because of loss of current or other reason, the brake

valve would automatically assume the functions of an ordinary pneumatic automatic brake valve and cause the triple valve to operate automatically, by making a brake-pipe reduction through the operation of its equalizing piston and equalizing discharge valve in the usual way.

In pneumatic service operation the brake-pipe reductions would be made entirely by means of the brake valve, while in pneumatic emergency operations the brake-pipe reductions would be produced by the brake valve and the quick-action portions of the triple valves all operating together, as with the old quick-action automatic brake.

PNEUMATIC SERVICE APPLICATION.

When a pneumatic service application is desired, the brake valve is moved to the same position as for electric service application, but the electric control is now assumed to be inoperative. The brake-valve parts then operate as any brake valve containing an equalizing piston and discharge valve, opening a port from the brake pipe to the atmosphere, which will allow a rate of brake-pipe reduction sufficiently rapid to move the equalizing parts of the control valve to their service application positions, which will, in turn, actuate the release parts, close the service cylinder exhaust port, and cause a pneumatic application of all the brakes in the train in the usual way. A partial or full pneumatic service application and the holding of the brakes applied until a further application or a release is desired are accomplished as with any ordinary pneumatic brake.

The above rate of brake-pipe reduction, however, as fixed by the brake valve, is less rapid than that with which the quick-action chamber pressure can be reduced through its feed groove into the brake pipe.

The flow of air from the auxiliary and service reservoirs to the brake cylinder, and the operation of the release piston are the same in pneumatic as in electric service operation.

PNEUMATIC EMERGENCY.

When it becomes necessary to stop in the shortest possible time, the brake-valve handle is moved to the emergency position and allowed to remain there until the stop is made and the danger has passed.

In this position, the emergency exhaust port of the brake valve is open, and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure in the first triple valve in the train cannot reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced through the brake valve, and, consequently, forces the emergency piston and its slide valve to move over to their emergency positions. The equalizing parts have also been moved over until the piston rests against its cylinder cap gasket.

The operation of the various valves is now the same as described under the "Electric Emergency Application."

In case the train should separate (the electric control of the brakes being in working order) the electric emergency would prevail on the forward end (due to current still being applied) and pneumatic emergency on the rear end (due to current being cut off by the separation).

PNEUMATIC RELEASE—GRADUATED.

When graduated release is desired the direct and graduated release cap must be placed in the graduated release position, as shown in the section. In this position of the cap the emergency and auxiliary reservoirs are connected when the release slide valve is in release position.

With the electrical portions inoperative, the release of the brake may be graduated as with any ordinary pneumatic graduated release brake, by moving the brake-valve handle to running position for a few seconds and then back to lap position. This will cause a slight increase in the brake-pipe pressure and move the equalizing parts to release positions, and this, in turn, will move the release parts (in lap position of the brake valve the brake-pipe port is closed, and, consequently, only a few pounds increase in brake-pipe pressure will result), but with the release parts in release position the emergency reservoir port is open, and, since this volume is not used in service operations, it will still have its initial pressure. The emergency reservoir air will now flow back into the auxiliary reservoir, and quickly raises the latter pressure to a point which is higher than that in the brake pipe, and consequently will move the equalizing piston and its graduating valve back from their release to their

graduated release lap positions, in which the release end of the release piston is open to the atmosphere and this piston and valve are moved to the application position in which the service cylinder exhaust port and the ports which connect the emergency and auxiliary reservoirs are closed, thus preventing a further increase in auxiliary reservoir and a further decrease of service brake cylinder pressure. During the time that the emergency reservoir port is open, allowing its air to flow back into the auxiliary reservoir, the release ports are connected, allowing a portion of the air from the service brake cylinder to flow to the atmosphere.

A further reduction of brake cylinder pressure cannot now be made until the brake-pipe pressure is again increased and the equalizing piston and its graduating valve moved to release position, when the above operation will be repeated.

The graduation of the release may be repeated until the brake-pipe, auxiliary, and emergency reservoir pressures are equalized, when the valves will remain in the release position and give the final release of brake cylinder pressure.

PNEUMATIC RELEASE—DIRECT.

If cars equipped with this valve are used in a train with cars that do not have the graduated release feature, the direct and graduated release cap should be set for direct release position, in which the emergency and auxiliary reservoir ports are separated, and the emergency reservoir cannot then flow back into the auxiliary reservoir when the parts are in release position.

Under these conditions, if the brake-valve handle were placed in running position for a few seconds and then in lap position, there would be no source of supply of air at a higher pressure (as furnished by the emergency reservoir in the case just described) to cause a return of the equalizing parts to graduated release lap position, and, consequently, a straight-away release of the brake cylinder pressure would occur.

PROTECTION FEATURE.

Should the motorman make an application and then let the brake-valve handle remain in lap position, the brake-pipe leakage would first cause the brake to equalize, and then, when this leakage has reduced the brake-pipe pressure to a certain pre-

determined point (which is governed by the tension on the protection valve spring), the protection valve will be moved from its seat and toward the right—this allows the quick-action closing chamber port to be connected to the quick-action and emergency switch piston ports and causes same to open and close respectively, which causes a venting of brake-pipe air to the atmosphere and also the instantaneous quick action or emergency, due to the emergency magnets being energized by the closing of the emergency switch.

Under these conditions the equalizing and release pistons and slide valves are already in the emergency position (which is the same as for service), and the opening of the emergency magnet valve causes the emergency piston and slide valve to move to the emergency position, and this, in turn, opens the emergency valve, and the reservoirs equalize with the brake cylinders, as hereinbefore described.

REDUCTION LIMITING FEATURE IN THE EQUALIZING PISTON.

Ordinarily, the service magnet makes a brake-pipe reduction by connecting the brake pipe to the brake cylinder: this then means that these two pressures are approaching each other, and as they near the equalizing pressure the rate of reduction in the brake pipe is gradually decreasing to zero.

In order to procure the desired pressure in the given time, then, the rate of reduction at first is quite rapid and the margin between it and the emergency rate is very small, and this margin is broadened as equalization is approached.

For those who may desire to have a uniform margin between the service and emergency rates of reduction, provision has been made to close the service magnet connection to the service brake cylinder and open same to the atmosphere. Then in order to limit the brake-pipe reduction to the equalization point, the reduction limiting check valve is embodied in the equalizing piston.

When the service magnet valve is open and the equalizing piston is moved over toward service position, the reduction in auxiliary reservoir pressure which follows the opening of the service port stops the movement of the equalizing parts before the reduction limiting check valve seats against the cylinder cap gasket.

If a continuous brake-pipe reduction is made, the equalizing

parts will remain in this position until the auxiliary reservoir and brake cylinder pressures have equalized; then a further reduction in brake-pipe pressure will cause these parts to be moved by the higher auxiliary reservoir pressure until the reduction limiting valve seals against the cylinder cap gasket, thus preventing an over-reduction in brake-pipe pressure.

To sum up the requirements and considerations of the electro-pneumatic brake equipment, we present the following:

1. *Fundamental Principles Relative to Electric Control of the Automatic Brake.*

1. The electric control system must not, either in its proper or improper action, or in its failure to act in any way, impair the stopping power of the automatic brake system.

2. During electrical control of brake applications, loss of current must not cause loss of braking power already obtained.

3. The opening of the application magnet valves must invariably be accompanied by the closing of any possible outlet to the atmosphere.

4. The application and exhaust magnets of the electric brake must be cut off from connection with the atmosphere when the brake is applied automatically.

5. The design of the electric brake should be such that it purposely actuates the control valve as with a pneumatic application, and a brake-pipe reduction must be made approximately equal to that required for an automatic application; that is to say, the operation of the electro-pneumatic brake must be as nearly as possible the equivalent in all particulars of the operation of the automatic brake.

6. The electro-pneumatic system is best which uses the same positions of the brake valve as the pneumatic and operates the brake in the same way.

7. The electro-pneumatic quick-action emergency is essential to the safety of modern trains and traffic; therefore, such a reserve of air must be preserved as will permit of an emergency application at any time.

2. *Battery Current.*

Battery current is considered fundamentally desirable to the satisfactory operation of the electric control of brakes, because

of its reliability, uniformity, and availability. It is immaterial how the battery is charged, provided it is of ample capacity.

3. *No Current at Brake Valve Unless All Jumpers in Place.*

The wiring scheme should be such that the fact that current is obtainable at the brake valve indicates in itself that all the jumpers are properly in place throughout the entire train; an interrupted control current is, in a degree, analogous to a closed angle cock in the brake pipe.

4. *Protection of Batteries.*

In steam road service, with means of obtaining the current from the car lighting systems, a device must be provided to prevent inadvertently cutting the brake supply wires on to more than one source of electrical energy at the same time.

5. *Train Signal.*

Electric operation of the train signal should be considered a part of the electro-pneumatic brake system.

6. *Universality of Equipment.*

Until recently the entire development of the automatic air brake has been along the lines so admirably laid down at the beginning by Mr. George Westinghouse, and each new form of equipment has worked in harmony with its predecessors. Owing to the enormous investment involved and the wide interchange of equipment throughout the country, this procedure has been of incalculable value to the railroads, and in the radical change in the method of control of the automatic brakes that we are considering it would seem to be equally necessary that this important principle be followed. It, therefore, is greatly to be desired that any new equipments be operative on their strictly pneumatic side with the present forms of automatic brake, during the necessarily very long transition period, and that the one or more systems of electric control that may have to be used must be interchangeable in their operation. This, however, should not be understood to exclude special installations such as now have (or may have) to be made with

pneumatic brakes, where interchangeability is not to be considered because of the isolated and local conditions.

7. *Electro-Pneumatic Brake Versus an Electrically-Controlled Automatic Air Brake.*

The ideal electro-pneumatic brake is one in which all functions are controlled electrically and the compressed air serves only as the medium of power transmission. Cars equipped with such a system would not be interchangeable with those having the present automatic brake, consequently the first essential would not be fulfilled, and to accomplish this the parts required to make an automatic air brake must be added. Again, in order that an electric system of control shall, in itself, be absolutely dependable, it is necessary that, as with the air control, loss of the controlling element shall set the brakes. Our experience with a purely electric system of control tested on the Boston Elevated Railway, in 1909, demonstrated that there were many ways in which the controlling element could be lost without manifesting the location of the cause, which in the case of air is so readily determined from the noise made when escaping. Hence such a system of electric control might necessitate the presence of an electrician on each train to promptly locate the cause of a loss of current or the installation of automatic indicators. As the air supply comes from the locomotives, a pipe to conduct the compressed air to the cars is necessary in steam train service. Such being the case, loss of air from the pipe of the brake system is with any design available to set the brake if the train breaks in two. At present, therefore, the practical electric control of the brakes must necessarily be built upon the automatic air brake as a foundation, and only such a system has been considered or advocated in this paper.

8. *Fundamental Requirements of a Brake.*

Among the fundamental improvements to the present pneumatic brake before it is wise to instal the electric features are that the emergency application be

First.—More quickly obtained than has been the case.
Second.—More powerful.
Third.—Obtainable at any time.

The Westinghouse Air Brake Company and the engineers of some of the railroads have taken the stand (1) that it is fundamentally necessary that the difference in time between the attainment of full cylinder pressure in service and emergency application *should be* the *greatest attainable* (assuming that the ready service application is as high as practicable; while (2) the difference in force should be at least 100 per cent.

9. *Relation of Electric and Automatic Emergency Applications.*

Since there can be only three objects in adding electric control to the automatic air brake, namely,

First—Increased safety (emergency);
Second—Reduction in time required to make stops (service);
Third—Instantaneous and simultaneous response and uniform application whereby the human equation relating to the manipulation is reduced to a minimum;

it follows (1) that the automatic air brake must be equal to the electric in every feature of emergency application, except that of time; (2) that no logical reasoning can justify the application of electro-pneumatic brake unless the preceding requirement is observed; (3) that an automatic air brake inferior to the electric is likely to be dangerous to a degree approximating the difference between the effectiveness of the electro-pneumatic brake and the automatic air brake, and, where great inferiority of the latter brake exists, the chances for disaster (when the electric control is inoperative when attempt is made to use it) are greater than if no electric control of the brake is employed, unless, of course, the same distances for signals, etc., be allowed as though the electric feature did not exist. (See curves on pages 132 to 140 inclusive of the August issue.)

10. *Rate of Emergency Application.*

In emergency applications maximum braking power should be obtained in the shortest possible time consistent with practical construction; this applies to both rate of transmission and

rise of cylinder pressure. In other words, it is not sound engineering to add the electric control to a pneumatic brake until everything practical has been obtained by proper design and installation of the pneumatic devices.

(By sound engineering is meant the best for the purpose (by purpose is meant the shortest practicable stop); but it does not follow that some compromise may not be best for the conditions.)

11. *Braking Power.*

The forces delivered to the brake shoes in emergency application should be at least 100 per cent. greater than that normally provided for in the design for the service brake.

12. *Extent of Electric Control.*

Use of electric control can be made in three ways—and this manifestly whether the improved pneumatic brake is used or not:

First.—To apply to both the service and emergency functions of the automatic brake.
Second.—To the emergency functions only.
Third.—To the service functions only.

In the first, the effect will be, as far as stopping distance is concerned, to leave the service and emergency brakes relatively the same as at present, and this applies, no matter whether the electric is applied to the old or improved forms of pneumatic brakes; the gain, however, will be two-fold. First, both the service and emergency stops will be shortened because of the elimination of the time element in getting the brake application started; and, second, shocks will be eliminated because of the simultaneous application of the brake.

In this connection it should be understood that the application of the electric control to any form of pneumatic brake will insure freedom from shocks, but if safety is the chief desideratum, this can be had to a much greater degree and for less expense than is possible by the mere application of electric control.

If applied as per No. 2, the gain will be, first, somewhat

greater safety due (*a*) to the simultaneous application of the brakes, (*b*) to the reduction of shocks, wheel sliding, etc., and (*c*) to the increase and effectiveness of the emergency brake over the service brake; second, the elimination of damaging and discomforting shocks so far as emergency application is concerned.

If applied to the third, that is, to the service functions only, the gain will be in the saving of time to get the brake applied, and in the elimination of shocks and discomforting surges, so far as service applications are concerned. However, the application is undesirable from the fact that it reduces the margin between service and emergency stops; in fact, it is possible to so make the installation that the electrically-controlled service stop would be shorter than if the stop was made with the strictly pneumatic emergency application.

Therefore it will be seen that an electric pneumatic installation in which the service application of the brake approximates in efficiency that of the pneumatic emergency is strongly defective.

From these considerations we conclude, first, that the greatest gain in every way can be had by adding the electric control to the most improved form of pneumatic brake; second, that it should be applied to both the service and emergency functions of the brake; and, third, that it should not be applied to the service brake only, but may be applied with considerable gain to the emergency brake only; and, fourth, that the application of electric control to the brake will contribute to safety, economy, and comfort to a degree impossible of attainment with a strictly pneumatic brake and to an extent far beyond any consideration of expense or complexity.

It is seldom that any one device or appliance offers the solution of so many problems, overcomes so many difficulties, and at the same time utilizes such a vast energy that now is dangerous or goes to waste.

This system eliminates time so far as brake initiation and propagation are concerned.

It eliminates retardation shocks, since it reduces brake operation closely to the effects as though one vehicle only was being retarded.

It reduces the human equation to a very low factor, as it is

so promptly responsive and flexible that correction of errors of judgment in manipulation can be made before inconvenience or damage can occur.

It is free from many of the shortcomings of other brake equipments, special care being taken to insure its immunity from influences (which unavoidably exist) that cause brake operations contrary to what are contemplated or when not desired.

It increases the safety of train operation, because full emergency braking force is available and obtainable always and instantaneously effective.

For "service" (station stops, etc.) operation, it is especially valuable from a revenue standpoint, as it permits of stops being made in much less time with a reliability, smoothness, and accuracy heretofore impossible.

It permits of accurate, instant, and comprehensive communication between the engineer and train crew, or *vice versa*, thus contributing largely to coöperation and efficiency.

It combines in one brake or train control equipment the two elements (compressed air and electricity) that seem intended to complement each other for this purpose; and, since the combination has proved in practice to be fully equal to its theory, it can hardly be called prophecy to say that its potentiality will be taken advantage of as it becomes known.

It is reliable, adaptable, and complete, and the writers have endeavored to so carefully and fully set forth the system as to permit those interested or concerned to verify all that is claimed for it. If this is accomplished, our purpose is served and much progress in this important and difficult field will have been made.

Federal Aid for Vocational Education.—This subject will be discussed at the annual meeting of The National Society for the Promotion of Industrial Education, to be held in Philadelphia on December 5, 6, and 7, 1912. Among the speakers are Ex-Senator A. J. Beveridge, Julia C. Lathrop, Hon. Caroll S. Page, author of the Page Bill, E. Geier, and others.

The different sessions of the society will be devoted to proposed legislation in vocational education, securing teachers for vocational work, vocational education in State and local communities, and many other topics of interest to manufacturers and educators.

PLATINUM: THE MOST PRECIOUS OF THE METALS.[1]

BY

HARRY F. KELLER, Ph.D.,

Member of the Institute.

WHEN I received the invitation to contribute a lecture to this season's programme of the Chemical and Physical Section, my thoughts, by reason of several circumstances, were so engrossed with the subject of platinum that I somewhat rashly promised to give a lecture on this in no sense novel theme.

Under the stress of other duties, I had almost forgotten my promise, when, about a month ago, I was informed that this evening had been assigned to me, and I was thus aroused to give some serious consideration to the task I had undertaken. Platinum! Of all subjects, why had I selected *it?* What new and interesting advances in our knowledge of the metal would justify my discussing it before an audience such as this?

On further reflection, however, it occurred to me that several reasons might be advanced in favor of my selection. In the first place, platinum, by virtue of many new applications in the arts, had become a subject of popular interest; secondly, that chemists, though constantly handling utensils made of the metal, are only in exceptional cases obliged to acquaint themselves with the special literature of the subject; and, thirdly, that the platinum group of metals, being almost invariably relegated to the last place in systematic courses in inorganic chemistry, is generally very briefly dismissed or not even reached in the lectures on this branch of chemistry.

In my own case platinum and the allied metals came into my range of interest very early in my scientific career, but for a number of years my interest in them had remained dormant until, some time ago, it was reawakened—first, by some assays and experiments which I made for a client, and again, in a rather unpleasant way, by an occurrence in the laboratory of the Central High School.

[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, April 11, 1912.

As you know, platinum vessels are extensively used in chemical experimentation and analysis. They constitute the most expensive part of the equipment in the chemist's workshop. As most of them are of small size, you will readily understand that in a laboratory to which many and all kinds of people have access the safe keeping of the platinum-ware not only necessitates special precautions, but also causes some anxiety now and then to those charged with it. Thus, in spite of the most explicit instructions, it will happen that a novice puts a platinum crucible out of commission while the instructor turns his back to him; and a fifty-dollar platinum dish may disappear from a desk as if it were made of the most volatile of substances.

I have been accustomed to handle and take charge of platinum apparatus of many descriptions and considerable value for a period of over thirty years. I had it impressed upon me with the first crucible I bought as a student that platinum must be treated with proper respect, and I have been fortunate in so far as I have never ruined a piece of platinum myself. There have been a few instances in which crucibles were damaged by students working under my direction, but until recently no theft of platinum had occurred in our laboratory, except, about a year ago, that of a small dish. Last fall, however, we had an experience which taught me that in addition to constant vigilance there is another precaution one cannot afford to neglect in taking care of the platinum stock of a large laboratory, and that is to keep it in a burglar-proof safe.

What happened then was briefly this. Returning to the school after an absence of several days, I opened the drawer in which I kept the platinum for general use in the laboratory, and discovered, to my amazement, that two of the larges dishes, worth at least $250, were missing. Otherwise the contents of the drawer, which contained many other platinum utensils, had not been disturbed, and the lock was perfectly intact. As the laboratory doors are always locked during the absence of the instructors, and only a few trusted employees of the school have access to these rooms, I was at a loss to account for the theft. I immediately reported the loss to my superiors, and with their approval, took what I considered the proper steps to recover the stolen articles. I furnished a description of the

latter to all the principal dealers of platinum goods, and called on the Chief of the city's Detective Bureau, who promptly detailed one of his best men on the case, and also had my description of the dishes printed and sent out to the "old gold" and pawnbroker shops in the city. Three days later the detective called me up on the telephone and informed me that the "cups" had been found, and that I should call for them at the City Hall. You can imagine how relieved I felt when the precious pieces were safe and sound in my hands once more, and without any expense for their recovery.

Just how the theft was committed is still a mystery. The dishes had been offered to a local dealer in "old gold," who at once suspected that they had been obtained in some dishonest way, and had cleverly managed to get possession of them without directly paying the money asked by the thief and his accomplice. On receiving the notice he turned the articles over to the Detective Bureau without asking for any reward. The description of the person who offered the platinum for sale, together with other evidence found later, leaves little doubt as to who the thief was, but an unfortunate combination of circumstances frustrated his identification.

My reason for prefacing my lecture with this incident is twofold: it shows that we cannot be too careful in providing a safe place for the keeping of our platinum-ware, and it may afford some useful hints as to what course to pursue in the event of a theft.

Let us now take up our subject in a methodical way, and begin in the good old-fashioned manner with an historical sketch.

Unlike most of the useful metals, platinum remained unknown until comparatively recent times. Probably the earliest authentic reference to it is to be found in a work of Antonio de Ulloa, a Spanish naval officer, published in 1748, and entitled "A Narrative of a Journey to South America." In this Ulloa mentions it under the name of platina as a mineral which occurs in the Choco District of Colombia, and which is found admixed to the gold of that district. He describes it as an extremely tough substance that renders gold unworkable, as it cannot be extracted or removed by any of the ordinary processes.

Specimens of platinum, probably from the same source, were brought to England as early as 1735 by Charles Wood, who obtained them at Cartagena, in Colombia. William Brownrigg, who received some of this material from Wood in 1741, and published a description of it as a metalloid in 1750 (two years later than Ulloa), is now generally credited with the discovery of platinum. For many years it was erroneously ascribed to William Watson.

A more complete investigation of platinum was made by Scheffer, assayer of the Stockholm Mint, and the results were communicated to the Royal Academy of Stockholm in 1752. His material came from the gold-bearing sands of the river Pinto, in Colombia, and he called the new substance "white gold, or the seventh metal, known in Spain as *platina del Pinto.*" Scheffer showed that platinum is a true metal, insoluble in nitric acid, but soluble in aqua regia; also, that it is infusible at the highest temperatures attainable in furnaces, but capable of forming fusible alloys with other metals and with arsenic.

Fairly pure platinum was first obtained by the German chemist Margraf, who made the important discovery that solutions of platinum chloride are precipitated by potassium and ammonium salts, but not by sodium salts. He also was the first to prepare spongy platinum. In 1778 the Count von Sickingen communicated to the French Academy the results of his experiments with platinum, in the course of which he found that the metal can be welded, and that it can be worked into foil and wire. A new process of rendering platinum malleable, by treatment with arsenic, was described by Achard in 1784. Macquer and Baumé succeeded in melting platinum in the focus of a powerful concave mirror. But in spite of all the work that was done on platinum during the latter part of the eighteenth century, it was not until the beginning of the nineteenth, and chiefly through the labors of certain Englishmen, that it yielded to metallurgical treatment and became a commercial product. In 1819 platinum was discovered in the gold placers of the Ural Mountains, and a few years later Russia became the chief source of commercial platinum.

The most important developments in the platinum industry were the perfecting, by Wollaston, of a process of making malleable platinum from the pure spongy metal, and the achieve-

ment of Deville and Debray, in 1858, of devising a process by which large quantities of the metal can be melted.

Owing to a rapidly increasing demand and a nearly stationary supply, the value of the metal has enormously increased in recent years, so that during the first decade of the present century the price of platinum has not only surpassed but more than doubled that of gold.

PLATINUM MINERALS.

In my experience as a teacher I have found that few words are so commonly misunderstood and incorrectly used as the simple term mineral. I may be pardoned, therefore, if I preface my description of the platinum minerals with a brief explanation of its meaning. In the popular sense we speak of minerals, or mineral products, to designate those materials which make up the solid crust of the earth, or which are taken out of "the bowels of the earth," in contradistinction to those which are derived from the animal and vegetable kingdoms. In the more specific sense, however, in which the term is employed in science, a mineral is a naturally occurring inorganic substance, having a definite chemical composition and definite physical characters, the essential feature being its homogeneity.

Now suppose we found such a natural substance to contain platinum and that this metal formed an essential part of its composition, we would then speak of this substance as a platinum mineral, and if it contained the metal in sufficient amount to permit of its commercial extraction, we would call it a platinum ore.

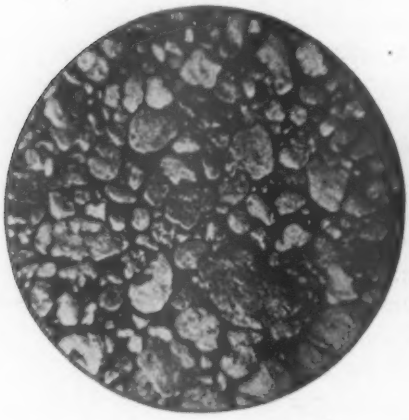
The mineralogy of platinum is extremely simple; for there are but a very few minerals that contain the metal, and only one of these constitutes an ore, and that is the *native platinum* from which the commercial metal is exclusively obtained.

But, although native platinum is not chemically combined with any other elements, it nevertheless invariably contains a number of other metals which are mixed or alloyed with the platinum. Among these must be mentioned five rare metals which are closely related to platinum, namely, iridium, rhodium, palladium, ruthenium, and osmium, as well as the more familiar ones,—iron, copper, and gold. For the reason

that native platinum is always host to a number of such guests or strangers, it has also received the name of *polyxenite,* meaning many strangers.

Native platinum occurs mainly in river sands and alluvial deposits, in the forms of grains, scales, and nuggets; the grains, though usually worn and rounded (Fig. 1),* not infrequently show distinct cubical crystallization (Fig. 2). The nuggets are usually small, though masses of considerable size, weighing up to 20 pounds, have occasionally been found in different localities (Fig. 3).

FIG. 1.



Thin, worn platinum grains, Colorado River, Colombia.

FIG. 2.

Rough unworn platinum grains, Tulameen River, British Columbia.

Owing to their exceptional occurrence, the larger nuggets have mostly found their way into collections of minerals.

Apropos of this, I can tell you an amusing anecdote, one of the few I have heard in connection with platinum. It is from Lewis's "Life of Goethe," and runs something like this: In the twenties of the last century a large and fine specimen of native platinum was included in a consignment from the Czar to the court of Saxe-Weimar, with the instruction that the specimen be forwarded to Doebereiner, then Professor of

* My grateful acknowledgments are due to Professor James Furman Kemp for kindly permitting me to copy this and other illustrations from his monograph on platinum and associated metals. U. S. Geological Survey Bulletin No. 193.

Chemistry at Göttingen. It was, however, first submitted to Goethe, friend and Prime Minister of the Duke, as well as an ardent collector of minerals. The poet took such a fancy to this curiosity that he quite forgot to return it or send it to its destination. Doebereiner, worried over the non-arrival of the promised treasure, wrote to Goethe, courteously inquiring as

FIG. 3.

Nugget of platinum, weighing 14 pounds, found at Nizhni Tagilsk in 1894.

to what had become of it. He received no reply either to this or to the more urgent inquiries that followed; so, as a last resort, he wrote directly to the Duke, imploring him to order Goethe to surrender the specimen. This was the reply: "Why bother the old fool? I will write to my brother-in-law, the Czar, and he will be pleased to send you another and even finer nugget."

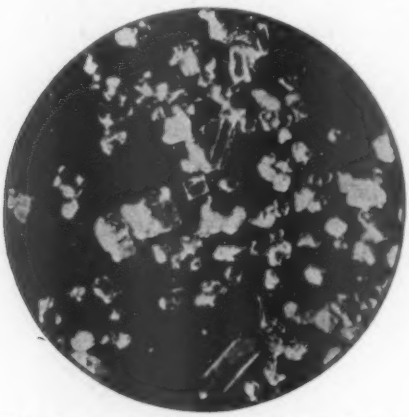
Native platinum has a grayish-white or gray color, and strong metallic lustre. It is malleable, and harder than gold

or silver. Its specific gravity varies within wide limits, say from 14 to 19, owing to the presence of iron and other metals. Some varieties are strongly magnetic, even showing polarity, while others are scarcely attracted by the magnet.

The chemical composition of native platinum from various localities is shown in the analyses given in Professor Kemp's admirable bulletin. The platinum content varies from 51.5 per cent. to 86.5 per cent., while the remainder is made up mainly of iron and the other platinum metals.

When the mineral contains very large proportions of iridium, so that the latter metal preponderates, it is called platiniridium.

FIG. 4.



Sperrylite in cubes from Vermillion Mine, Ontario.

This variety, which may contain over 75 per cent. iridium, is extremely rare. It is whiter and harder than platinum, and is the densest of all minerals, its specific gravity being nearly 23.

Small proportions of platinum are found in a few rare minerals, such as *native palladium* and *iridosmine*. The only known compound of platinum that has so far been met with in Nature is *sperrylite*, an arsenide of the metal, $PtAs_2$. It is likewise a very rare mineral, and has been found only in a few localities, notably in a copper mine near Sudbury, in the western part of Ontario (Fig. 4).

Sperrylite forms very small, shining crystals, similar to those of pyrite. It is hard and brittle, and has the specific gravity 10.6.

In addition to the true platinum minerals, some other minerals which are commonly associated with native platinum in the gravels, and often attached to the nuggets, should be mentioned here. It is through studying these associations that geologists may expect to find clues as to the original home of the metal in the mother rock. The most important of these

FIG. 5.

Platinum nugget with olivine and octahedral chromite, Tulameen district, British Columbia (after Kemp).

companions of platinum are chrome iron, olivine, serpentine, pyroxene, and native gold (Fig. 5).

These and a number of other dense and hard minerals which accompany the platinum are the same as those usually found in the gold-bearing gravels and sands, and must be regarded as fragments worn away from the rock in which these metals were originally deposited.

A very complete and thorough discussion of the work done can be found in Professor Kemp's bulletin on "Platinum and Associated Metals," published in 1902. According to Professor

Kemp, this has been accomplished in a few instances, but the quantities of platinum that have been found in the country rock are so small that the commercial extraction of the metal from such rocks is out of question. My own experience seems to confirm this.

FIG. 6.

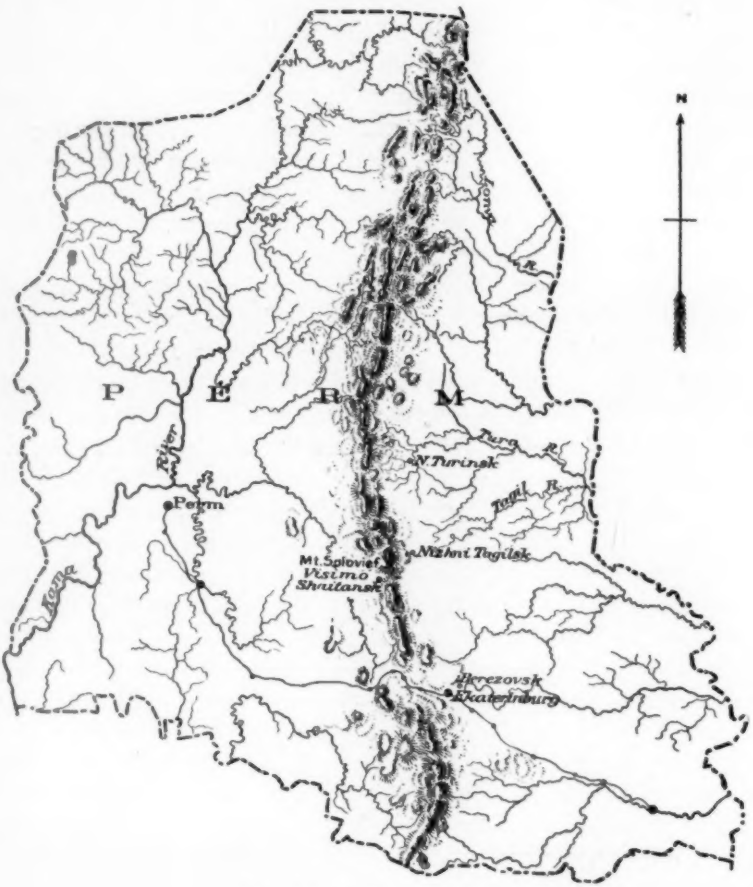
Map of Colombia.

SOURCES OF COMMERCIAL PLATINUM.

While native platinum has been reported from many and widely scattered localities, both of the Eastern and Western Hemispheres, the districts which have produced the metal in commercial quantities are few in number and limited in extent.

As I have stated before, platinum was first observed in the gold placers of Colombia. The river Pinto, from the sands of which were obtained the first specimens that were brought to Europe, is doubtless one of the tributaries of the San Juan, in

FIG. 7.



Map of the Government of Perm.

the district known as El Choco (Fig. 6). Before the discovery of platinum in the Ural Mountains, Colombia furnished the bulk of the metal of commerce, and, while its production at the present time is probably only one-twentieth that of Russia, it still occupies the second place as a platinum producer. It is

estimated that Colombia has yielded over 50,000 pounds of platinum, mostly from the San Juan district.

Among the earlier finds of platinum, those made in the gold washings of the island of San Domingo, and especially the province of Minas Geraës, in Brazil, are often mentioned. It does not appear, however, that either of these localities has ever contributed appreciably to the world's supply.

It was not until 1819 that platinum was first observed in Russia. In that year small quantities of grayish-white metallic grains were gathered in the gold washings of Verk-Isetsk, in the Siberian Urals. They were not recognized as platinum until 1823. The development of the great deposits at Nizhni Tagilsk began in 1824, and in the following year the metal was found also in the Goroblagodat district.

Since that time the metal has been found in many other localities in the government of Perm (Fig. 7), but those which have produced the bulk of the commercial metal are in the districts southwest of Nizhni Tagilsk and northwest of Nizhni Turinsk. The Goroblagodat and Bisersk districts on the northeast of the latter place are at present the most active producers of the metal.

Outside of Russia and Colombia, platinum has been produced, though only in comparatively small quantities, in California, Oregon, Washington, British Columbia, Borneo, and New South Wales. Great efforts have been made in recent years to increase the output, especially in British Columbia and in New South Wales, but apparently without success.

EXTRACTION AND PURIFICATION.

Since the platinum of commerce is exclusively derived from alluvial deposits, the methods employed for its recovery are essentially similar to those employed in gold placers; indeed, if we except the Uralian districts, it may be said that platinum is generally obtained as a by-product in gold washing.

The Russian platinum-bearing gravels, which are covered with barren material, from a few feet to 50 feet in depth, are worked partly by open mining, but usually by sinking shallow shafts and drifting along the pay streak. The latter, as a rule, is only a few feet in thickness, and the gravels are said to run from .05 to 1 ounce per cubic yard.

The washing plants are mostly of a peculiar, rather primitive construction, though quite recently modern methods and apparatus have been successfully introduced on some of the properties.

(For descriptions and recent improvements in the recovery of platinum, with or without gold, see Mineral Resources, 1905–1906.)

The metal obtained by washing and various concentrating processes, and freed from gold, constitutes the crude platinum, or platinum ore, of commerce.

As we have seen, this contains various metals that render the platinum unworkable, and the ore has to undergo a refining process to convert it into the commercial form.

Many attempts to render platinum malleable and ductile were made during the latter part of the eighteenth century, and while a few men, like Achard, the Count von Sickingen, and the skilful metal workers Chabanneau and Jeannetty, of Paris, succeeded in doing it on a small scale, it was not until the early years of the nineteenth century that the platinum industry was really founded, and the creators of this industry were Englishmen.

About the year 1800 Charles Knight devised a process which, while still imperfect, embodied the principal features of the method by which all commercial platinum was obtained for more than fifty years. It consisted in dissolving the crude metal in aqua regia, precipitating the solution of the chloride with sal ammoniac, then packing the dried precipitate into conical moulds of fire clay, and strongly heating it in the mould. It is said that the metal was thus obtained as a coherent mass which could be hammered and worked into various forms.

The product, however, still lacked solidity and homogeneity, and it was only by certain important modifications and improvements that it became a commercial success. The improved process is usually credited to the chemist Wollaston, but according to Roscoe the main features were invented by a relative of a member of the firm of Johnson & Matthey. However that may be, it is certain that the improved process was first described by Wollaston in the Bakerian Lecture for 1828, and Faraday, who was undoubtedly well informed on the subject, said in a lecture on platinum, delivered in 1861, "This sub-

stance has been given to us hitherto mainly through the philosophy of Dr. Wollaston."

In the process described by Wollaston the double chloride of platinum and ammonium was very carefully heated to a temperature just high enough to expel the ammonium salt, whereby the cohering of the resulting particles of metal was prevented. The product was then rubbed by hand, sufficiently fine to pass through a lawn sieve. It was then made into a uniform pulp with water, and this was placed into a brass cylinder, where it was powerfully compressed by means of a lever. The hard cake which resulted was heated on a charcoal fire; to expel the water and promote cohesion, and finally heated at the highest temperature attainable in a wind furnace. By forging the white-hot cake under a heavy hammer, it was consolidated into an ingot, which could be beaten into thin sheets and drawn into the finest wire. The refractory natural product had been conquered, and henceforth platinum was one of the useful metals.

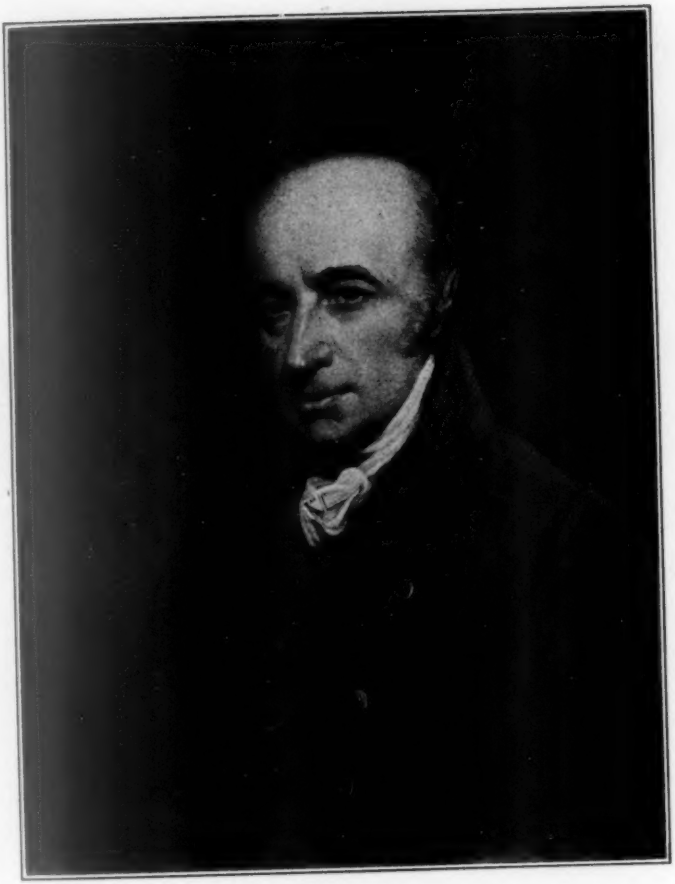
That platinum is not infusible was shown in 1758, when Baumé and Macquer succeeded in melting grains of the ore by the aid of a concave mirror; but the melting of considerable quantities of the metal was a feat which was first accomplished in our own city: in 1847 Robert Hare demonstrated that the difficult and tedious process of consolidating platinum sponge could be replaced by the simple operation of fusing the metal in the oxyhydrogen flame. He melted as much as two pounds of platinum at a time.

His process was greatly improved by the French chemists Deville and Debray, and it was through them that it became more generally known, and that it was adopted by the platinum refiners.

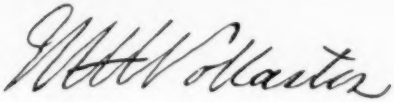
Deville's furnace consists of two well-fitting pieces of quicklime, hollowed out to form a crucible or hearth. An opening at the side serves as a spout for the molten metal and for carrying off the fumes and products of combustion. The nozzle of the oxyhydrogen blowpipe is introduced through an opening in the centre of the cover.

Lime is used because it is infusible at the temperature of the flame, and because it is porous and absorbs the slags formed during the operation. It is also a poor conductor of heat.

I had the privilege of seeing this process in operation at



WILLIAM HYDE WOLLASTON, M.D. F.R.S.



the Heræus works at Hanau. Although they used illuminating gas instead of hydrogen, it was amazing to see the platinum sponge and scrap melt like butter as fast as it was fed in. You cannot, however, distinguish the metal from the lime, as both glow with the same intensity, and one must also protect the eyes with dark glasses when looking into the furnace. At the Heræus works I was shown all the principal operations, from the treatment of the ore with aqua regia, to the production of the ingot. Incidentally I also learned how such by-products as iridium, palladium, rhodium, and osmic acid are obtained and handled.

Although several methods have been proposed for the refining of platinum, it appears that the treatment of the ore in the different works is essentially the same; for there is little difference in the manufactured product, whether it come from London, Paris, Hanau, St. Petersburg, or our American refineries.

At the Heræus works the ore is boiled under pressure with dilute aqua regia, whereby the platinum and some of the associated metals pass in solution in the form of chlorides, while the iridosmium and gangue remain undissolved. The chloride solution is evaporated to dryness and heated at 125° C. The residue is then dissolved in water, acidified with hydrochloric acid and precipitated with sal ammoniac. The resulting double chloride, containing only small amounts of other metals, is finally reduced in the manner which I have already described.

The refining of platinum in the dry way, as proposed by Deville and Debray, does not seem to have proved successful, except in special cases and on a smaller scale.

The preparation of chemically pure platinum, *i.e.*, a product which is entirely free from iridium, rhodium, etc., is extremely difficult and tedious, and need not be discussed here.

PROPERTIES OF PLATINUM.

To tell an audience of chemists and students of chemistry about the properties of platinum would be like carrying coals to Newcastle. Some of the physical constants of the metal, it is true, have in recent years been redetermined and revised, but the corrections which have thus been made on the older figures have had no marked influence on the applications of the manufactured product.

What interests us here are those properties, physical and chemical, to which platinum owes its unique position among the useful metals, and its manifold applications in the arts.

The characteristic color and lustre of the metal, though long familiar to the chemist, have only in recent years caught the popular fancy, and their noble ornamental effects are just beginning to be appreciated. The specific gravity of pure platinum is 21.48, but that of the manufactured metal varies considerably, according to the manner in which it has been obtained, and is affected also by the impurities which are present in it. Pure platinum is quite soft, flexible, and extremely malleable and ductile. Like wrought iron, it can be welded at a white heat. Its coefficient of expansion is the same as that of certain kinds of glass. Its melting point is somewhat above 1700° C. (or about 3100° F.), and at still higher temperatures it volatilizes. Moissan has shown that it can be distilled in the electric furnace.

At a red heat it is markedly pervious to hydrogen gas, which is due to the fact that it combines with or absorbs this gas at high temperatures. It forms fusible alloys with many of the metals.

One of its most valuable properties is that it does not tarnish or combine with oxygen, even at high temperatures. In the molten state it does absorb some oxygen, which, however, escapes when the metal solidifies.

As many of us know from sad experience, platinum is readily attacked at higher temperatures by sulphur, phosphorus, arsenic, and silicon, and, under certain conditions, also by carbon.

You also know that platinum is practically proof against the attacks of all acids, except the mixture of hydrochloric and nitric acids. It is, however, dissolved by nitric acid when alloyed with large amounts of silver.

It is also slowly attacked by fused pyrosulphates, and more rapidly by fused nitrates and caustic alkalies.

In the finely divided states of platinum black and sponge, and even as fine wire and thin foil, it produces many remarkable chemical effects, acting as a catalytic agent, especially in the oxidation of many gases and vapors.

Colloidal solutions of platinum have been obtained in a number of ways.

USES OF PLATINUM.

Platinum has not inaptly been called "white gold." Its physical and chemical properties closely resemble those of the yellow metal with which it is generally associated in Nature. But in addition to the many virtues which it shares with gold, platinum has several most valuable properties of its own, and it is chiefly to these that it owes its many uses in science and in the arts.

On account of the great difficulties which had to be overcome in freeing platinum from the other metals with which it occurs in Nature, it was many years after the discovery of the metal before it found any practical applications. The first platinum crucible is said to have been made by Achard. It must have been a very crude affair. The German chemist's process of rendering platinum malleable was improved by the Paris goldsmith Jeannetty, who enjoyed a great reputation for the platinum goods he turned out. I suppose the prototypes of the meter and kilogram were made by his process.

At the beginning of the nineteenth century vessels made of platinum were still so scarce and costly that very few chemists could boast of possessing such apparatus. It was not until the London firm of Johnson & Matthey and the chemist Wollaston developed their method of rendering platinum workable that wire, foil, crucibles, and other articles made of the metal came into more general use. As early as 1809 Johnson & Matthey manufactured a platinum still for the concentration of sulphuric acid which weighed 424 ounces.

It would be difficult to overestimate the effects which the use of platinum apparatus has had on the progress of the sciences and arts. Writing in 1844 Liebig thus characterized the part which platinum plays in the chemist's workshop: "Without platinum it would be quite impossible to carry out a mineral analysis. To render the sample soluble, it must first be fused with suitable reagents. Glass and porcelain, or any other non-metallic substance of which crucibles are made, would be rapidly destroyed in this operation, while crucibles made of gold or silver would melt at the high temperatures at which the fusions are made. Platinum is cheaper than gold, harder and more resistant than silver, and infusible at the highest temperatures

of our furnaces; it combines the valuable properties of gold with those of porcelain. Without the use of platinum the composition of most of the mineral species would still be unknown."

That platinum crucibles were freely used in Liebig's famous laboratory is reflected by a little incident which is told by one of the biographers of the great chemist. It happened that a Paris manufacturer of platinum-ware stopped off at Giessen and visited the laboratory. On being asked whether he wished to see the Director, Professor Liebig, he replied: "M. Liebig? Who is he? I have never heard this name. Show me the way to the excellent M. Aubel. I have sold him many crucibles." Aubel was the *Diener,* or factotum, who had charge of the supplies.

But since the days when there was only one great teaching laboratory in the world, wonderful strides have been made in chemical experimentation and analysis, and the demand for platinum apparatus has grown enormously. In addition to the myriads of crucibles, of various shapes and sizes, chemists now require a host of other platinum utensils, such as dishes and trays, spatulas, tubes, distilling apparatus, electrodes, etc.

As some conspicuous instances of successful experimentation which depended on the use of platinum apparatus, I may mention Moissan's great work on the isolation of fluorine and the proof by Mme. Curie and Mlle. Gleditsch, that the action of radium emanation on copper solutions does not produce any lithium, as Ramsay had supposed.

While platinum is less in evidence in the equipment of physical laboratories, it enters into the construction of a great number of apparatuses and instruments which are employed in the study of heat, electricity, spectroscopy, and the recently-discovered radiations. Much of this apparatus is made of glass, and in providing it with attachments of platinum wire and plates advantage is taken of the fact that platinum and glass expand and contract at the same rate. The coefficient of expansion of platinum is also utilized in the Breguet thermometer.

The application of platinum in the arts is extremely varied, and would be even far more extended, if it were not for the high price and the limited supply of the metal.

The nozzles of the oxyhydrogen and the oxyacetylene blowpipes which are used for cutting iron and steel, as well as for

fusing platinum, quartz, and other highly refractory materials, are often made of platinum.

In the manufacture of sulphuric acid, both by the leaden chamber and the contact processes, the metal is used in very large quantities. Since Johnson & Matthey constructed their first platinum still in 1809, this old firm and other manufacturers have furnished a great number of such retorts, and of much greater capacity, to sulphuric acid works in all parts of the world. In the newer contact process, as well as in other chemical manufactures which depend on catalytic action, platinum sponge or platinized asbestos are largely used as the "contact materials." Enormous quantities of platinum also are consumed in the manufacture of electrical appliances, especially of incandescent lamps and the sparking points for internal combustion engines.

But, impressive as are the quantities of platinum required for the purposes I have mentioned, they are equalled, if not exceeded, by those which are absorbed in the manufacture of dental supplies. It is estimated that fully 50 per cent. of the platinum of commerce is consumed in the production of pins, sockets, and other attachments of artificial teeth.

Passing over some minor uses of platinum, as in the construction of standards, the manufacture of surgical instruments, electroplating, china painting, pyrography, etc., it still remains for me to call your attention to another application, which, while not entirely new, has only recently assumed very considerable proportions. I refer to its use in jewelry. For many years parts of jewelry—for instance, of chains, rings, and scarf-pins, etc.—have been made of platinum, on account of the pleasing contrast of its color with the various shades of gold; but it is only in recent years that the beauty of the metal has come to be fully appreciated. At the present time the greater part of the more elaborate settings of diamonds and pearls, as well as a great number of other articles of jewelry, are made of this metal.

A question that naturally suggests itself here is as to whether so precious and noble a metal as platinum is not available for coinage. Aside from its great intrinsic value, its fine and permanent lustre, and its high specific gravity, it readily takes the impression of the die and is harder and tougher than gold and silver. It is probable that in the early years of its discovery

in Colombia considerable quantities of platinum passed into the Spanish coin-gold; while later the Spanish Government is said to have issued an order directing its officials to dispose of the objectionable companion of gold by casting it into the sea; and still later the King decreed that the entire output of platinum be delivered to the Crown. It is believed that much of this platinum was used to debase the Spanish coinage.

In 1828, when the Russian Government had accumulated enormous stores of platinum from the Uralian districts, it was decided to convert this surplus into coins, and accordingly three denominations—of 3, 6, and 12 rubles—were minted and put in circulation. This minting of platinum continued until 1845, when it was stopped and the coins were withdrawn from circulation. The reason for this was that, the Russian Government being unable to fix and maintain the price of the metal, large quantities of the coins passed into other countries. Many of them are still preserved in the collections of numismatists. Those shown on the screen are in the collection of the United States Mint in this city; others can be seen in the loan collection in Memorial Hall.[2]

The metal from which these coins were made was not pure platinum. According to Faraday, it contains platinum, 97.0; iridium, 1.2; rhodium, .5; palladium, .25; together with traces of copper and iron.

Just as gold and silver are alloyed with copper (and other metals) to increase their hardness and wearing qualities, so platinum is often alloyed with iridium to increase its resistance to abrasion and the attack of chemicals. Such an alloy goes under the name of "hard" platinum, as distinguished from ordinary platinum. It is more expensive than the latter. Thus most of the vessels used by chemists contain about 2 per cent. of iridium, while much larger proportions of the latter—from 10 to 15 per cent.—are added to the platinum used for the construction of standards of length and weight, for electrodes exposed to severe chemical attack, for sparking plugs, and the points of fountain pens.

For special purposes platinum is sometimes alloyed with

[2] I am indebted to the kindness of Dr. Jacob B. Eckfeldt, Chief Assayer of the Philadelphia Mint, for obtaining permission to photograph these coins.

Russian platinum coins. From the collection in the Philadelphia Mint.

Russian platinum coins. From the collection in the Philadelphia Mint.

other metals. An alloy with rhodium is used in certain electric pyrometers; and various alloys with copper, nickel, tungsten, and manganese serve as substitutes for steel in the construction of non-magnetic watches.

Of the compounds of platinum, only a few have found application in analytical chemistry, photography, and physics.

The most important, platinum chloride, or rather chloroplatinic acid, is an invaluable reagent; and barium platinocyanide is used on account of its fluorescence, which converts the ultra-violet rays and X-rays into visible radiations. The shadows made by X-rays are best projected on screens coated with this salt.

SUBSTITUTES FOR PLATINUM.

In view of the great increase in the price of platinum it is but natural that many and persistent attempts have been made to find substitutes for it. In a few instances this has been partially, or even wholly, accomplished; as yet, however, the introduction of such substitutes has had no appreciable effect upon the price of the metal; indeed, it may be said that the demand for platinum has steadily increased in spite of them.

Among the substitutes may be mentioned platinum-clad nickel steel wire, which is beginning to displace the solid wire in incandescent electric lamps; wires of nickel alloys which are used in making the cheaper grades of artificial teeth; asbestos threads which have replaced platinum wire in the Welsbach mantles; and the fused-quartz ware, now so extensively employed in chemical laboratories in the place of platinum utensils.

Perchloric acid and sodium cobaltic nitrite are useful in saving platinic chloride in the laboratory.

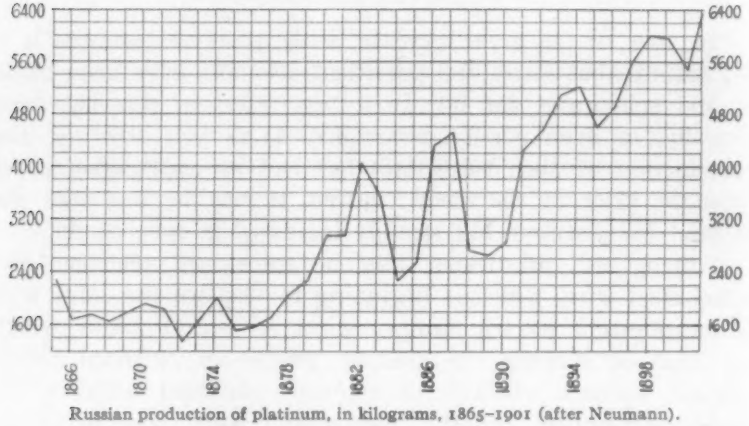
PRODUCTION.

Statistics on the production of platinum, from the time when it first appeared on the market up to the present, may be found in many publications. An excellent *résumé* up to the year 1901 is given by Dr. B. Neumann in his work "Die Metalle." Our time does not permit of a full discussion of this subject, and I shall content myself, therefore, with a few quotations from this work and some more recent reports, chiefly

those published in the "Mineral Resources of the United States."

It is estimated that up to 1778 the entire output of Colombia amounted to 1,943 kilograms; that is, about two tons of the metal. According to Humboldt, the annual production at the time when platinum was discovered in Russia was 545 kilograms. After that the Colombian production gradually decreased. Neumann estimates that up to 1900 Colombia had yielded from 16,000 to 20,000 kilograms. In 1906 the platinum exported from Colombia was 6,813.38 troy ounces (about 200 kilograms).

CHART I.



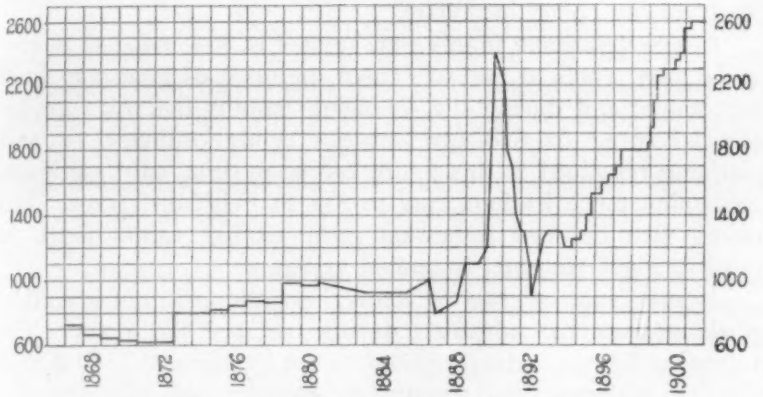
Russian production of platinum, in kilograms, 1865–1901 (after Neumann).

The production of platinum in the Uralian districts began in 1824. From that year until 1845, when the coinage of platinum stopped, it amounted to 30,381 kilograms, of which Nizhni Tagilsk furnished 29,542 kilograms. From that time up to 1864 about 12,000 kilograms were mined in the Urals, and the graphic representation on the screen, borrowed from Neumann, shows the fluctuations of the annual output of Russia, since 1866. It indicates a fairly steady increase since 1875. During the last few years it has been approximately 6,500 kilograms, or somewhat above 200,000 ounces. It should be stated here that the official figures are probably 20 to 25 per cent. below the actual production, owing to the well-known fact that much of the metal is stolen at the mines.

In the United States the production of platinum has been very irregular; it now amounts to several hundred ounces a year: in 1906 a high record was reached with 1,439 ounces, valued at $45,189. Statistics of the production of platinum in British Columbia, Borneo, and New South Wales show great fluctuations, but the totals are quite small, and have probably not reached 100 kilograms in any one year.

The distribution of platinum in the principal industries was estimated by Siebert (writing in 1902) to be as follows: 50 per cent. for dental manufactures; 30 per cent. for chemical

CHART II.



Price of platinum, per kilogram, in marks, 1867–1901 (after Neumann).

and electrochemical industries, and 20 per cent. for electrical manufactures and jewelry. The use of platinum for jewelry has greatly increased since 1902.

THE VALUE OF PLATINUM.

During the three or four decades which followed the discovery of platinum in Colombia the valuable properties of the new metal remained unrecognized, and it was then regarded as an undesirable companion of gold. As late as 1778 the Spanish Government ordered all platinum to be sent to the royal treasury, without any compensation. Subsequently, the munificent reward of two dollars per pound was paid by the Crown, but the miners found it more profitable to sell it to English traders, who paid

$12 per pound and then sold it at a much higher price in Europe. Humboldt states that in 1819 the price of the metal on the spot was $8 a pound, while it sold in Paris for nearly four times that amount.

The first platinum found in Russia was sold for $3 a pound. In 1825 the lessee of the Nizhni Tagilsk placers paid $3.50 to $7 a pound, and sold it at $14 to the Imperial Mint.

In 1867 the firm of Johnson, Matthey & Co. paid more than $25 per pound for the crude metal, and in 1877 the price had risen to nearly $40. Our diagram, which is also borrowed from Neumann, shows the fluctuations in the price of platinum, per kilogram, in marks. Dividing the latter by 8, we have roughly the price per pound in dollars.

In 1902 platinum ingots were quoted at $18 per troy ounce; in January, 1906, at $20.50 (about the price of gold, $20.672) per ounce; and during the following months the price gradually advanced to $38 per ounce. While ordinary or soft platinum remained at this figure for some time, hard platinum, containing much iridium, rose to $41 in February, 1907. The prices then declined somewhat, only to rise again, until, at present, ingot platinum is quoted at $45.50.

It may interest you to know how the price of chemical platinum-ware has advanced during the past ten years. The following figures were furnished to me by Messrs. J. Bishop & Co., of Malvern, Pa., through the courtesy of Mr. Geo. D. Feidt:

	1902.	1912.
Crucibles, per gram.....	$ .75	$1.70
Foil	.60 to .70	1.55 to 1.65
Wire	.60	1.50
Gauze	.95	1.95
Sponge	.60	1.50

In thus concluding my lecture on platinum I am well aware that I have only lightly touched upon the chemistry and other scientific aspects of the subject. My main object was to show the causes which have operated in advancing the once-despised by-product of the gold placers to the rank of the most precious of the useful metals.

THE DIFFUSE REFLECTING POWER OF VARIOUS SUBSTANCES.[1]

BY

W. W. COBLENTZ, Ph.D.,

Associate Physicist, U. S. Bureau of Standards.

I. INTRODUCTION.

In all radiometric work involving the measurement of radiant energy in absolute value it is necessary to use an instrument that intercepts or absorbs all the incident radiations; or, if that is impracticable, it is necessary to know the amount that is not absorbed. The instruments used for intercepting and absorbing radiant energy are usually constructed in the form of conical-shaped cavities which are blackened with lampblack, the expectation being that, after successive reflections within the cavity, the amount of energy lost by passing out through the opening is reduced to a negligible value.

A simpler and older form of radiometer is a plane surface covered with an absorbing substance. In this case it is necessary to determine the amount of energy lost by reflection from the surface of the receiver. If the blackened receiving surface is small it may be placed at the centre of curvature of a hemispherical mirror, the radiant energy being admitted through a hole in the centre of the mirror. The receiver being at the centre of curvature of the mirror, any radiations which are diffusively reflected from the receiver will impinge upon the mirror and will return to the receiver. The amount of energy lost by returning upon its path through the opening in the mirror can be determined experimentally.

The most useful substances for absorbing radiant energy are lampblack and platinum black. The present research was undertaken in order to establish methods for the production of standard absorbing surfaces from standard materials, and to determine the completeness of the absorption (*i.e.*, the amount

[1] Extract from a paper to be published in *The Bulletin of the National Bureau of Standards.*

lost by diffuse reflection) of these substances in different regions of the spectrum.

The reverse problem was also presented, of finding a "white" surface, which absorbs the least radiation (high reflection) in the visible and in the adjoining infra-red part of the spectrum, and which has a low reflection in the region of 8 to 9 μ. By this means the surface would absorb but little sunlight; and it would not become heated by the part that is absorbed, owing to re-radiation, which is facilitated by the high emissivity in the region of 8 to 9 μ, where occurs the maximum radiation of substances having a temperature of 20° to 50° C.

Expressed in a more popular way, the interest in the present research was in finding the substances having the extremes in diffuse reflection, *i.e.*, the "whitest" white and the "blackest" black—the former to be used as a paint (which will absorb but little of the sun's rays) to cover a building (*e.g.*, observatory dome) which is to contain instruments that are sensitive to changes in temperature; the latter to be used as the absorbing surface of a radiometer which is located within this building.

While it is beyond the scope of the present investigation to discuss the theoretical aspects of this subject, it is of interest to notice the extraordinary, and apparently inconsistent, ways in which these extremes in diffuse reflection are produced. In optically transparent media (insulators), such as glass, the absorption coefficient and the refractive index are low; and the amount reflected regularly ("specular reflection") is of the order of 4 to 5 per cent. On the other hand, in the metals (electrical conductors), such as platinum, the absorption coefficient and the refractive index are high; and the amount reflected regularly is of the order of 80 to 100 per cent., depending upon the wave-length. On first consideration it therefore seems somewhat contrary to the natural order of things to produce a high (90 per cent.) reflecting (diffuse reflection) surface from the former, and an extremely low (2 per cent.) reflecting surface from the latter, by merely changing the size of the grains which form the reflecting layer.

The high reflecting power of fine particles of transparent substances (insulators) is easily explained as the result of successive internal reflections and refractions of the light which penetrates their surfaces. If the particles are small the chances

are that total reflection will occur before the rays have penetrated to a great depth, and (there being practically no absorption) the rays are reflected with almost the same intensity as obtained in the incident radiations.

When the reflecting particles have a high absorptivity, but have a low refractive index, which is true of lampblack, the same optical conditions obtain as in the more transparent particles, the only difference being that at each internal reflection the rays are further absorbed so that the intensity of the reflected rays is quickly reduced to a small value in comparison with the incident rays. The blackest deposits of soot are made by holding a metal plate in an acetylene flame, which forms an extremely fine-grained surface. Such a deposit, viewed at grazing emergence, has the appearance of a highly-polished mirror of fairly high reflecting power.

The effect of grain size upon the amount of energy (diffusively) reflected from the surface is well illustrated in the present paper, which gives the reflecting power of a cleavage surface and of a coarsely-ground surface of white marble. The cleavage piece (about 1 cm. thick) was well illuminated throughout the interior to the rear surface, owing to the large size of the individual crystals, some of which had cleavage faces 0.2 to 0.3 mm. diameter.

The low reflecting power obtained by reducing the size of metallic particles (*e.g.*, platinum black) to the dimensions of light waves is not so easily explained. If the black mass is a coagulation of colloidal metal its optical properties (refractive index, etc.) are the same as that of the metal.[2]

Evidently it is not a question of roughness of surface, for a deposit of platinum black (upon a strip of platinum) when heated to a low red heat sinters into a white mass. By eliminating the high reflecting power, platinum could become black by assuming a structure of fine particles, which consist of cavities with small openings. Such a condition would be realized if the material had the structure of a bundle of polished needles,[3] turned with their points toward the light. By multiple reflection

[2] Spence, *Phys. Rev.*, 23, p. 233, 1909.

[3] Kurlbaum, *Ann. der Phys.* (3), 67, p. 855, 1899.

Wood, Physical Optics, New Edition, p. 449, "Absorption by Porous Surfaces."

the rays will travel down into the interstices between the needles (particles forming the spongy mass), and practically none will escape by reflection back upon their path. It is conceivable that by electrolysis the platinum black might be deposited in isolated points with relatively large spaces intervening, and that, as the electrolysis continues, these points increase in height and diameter, thus forming a porous, needle-shaped structure. This would increase the absorption of electrolytically-deposited platinum black (as observed), but it does not fully explain the physical condition of the chemically-precipitated material, unless we assume that the latter, which is colloidal, was built up in a similar manner by coagulation.

A more plausible explanation, alluded to by Kurlbaum, is based upon the depth of penetration of the rays into the metal and the thickness of the reflecting layer. In order to obtain reflection, a definite thickness of metal is required, which thickness is a function of the wave-length of the incident light. Hagen and Rubens [4] determined the reflecting power of gold with thickness on the assumption that the layer is homogeneous—*i.e.*, not formed of discrete particles with intervening spaces of glass. They found that for a layer 0.01 μ in thickness the amount of light reflected was about 10 per cent. of the total reflecting power for that wave-length. The maximum thickness required for complete reflection of all wave-lengths was about 0.08 μ. The smallest particle of colloidal material (*e.g.*, gold) observable in a microscope is of the order of 0.01 μ.[5] It is conceivable that there are colloidal particles which are still smaller, and that platinum black is made up of aggregations of these invisible particles. In this case it is conceivable that if the thickness of the particle is less than the minimum thickness required in the transition layer to obtain reflection, then the rays will pass through the particle, diminished in intensity by the amount absorbed in the particle. This is the (somewhat elaborated) view taken by Kurlbaum (*l.c.*), who based his line of argument upon Stark's [6] investigations of the physical properties of soot. In a deposit of soot, Stark considered the air a turbid medium, containing the particles of soot.

[4] Hagen and Rubens, *Ann. der Phys.* (4), 8, p. 432, 1902.

[5] Burton, *Phil. Mag.*, 2, p. 425, 1906.
Spence, *Phys. Rev.*, 23, p. 233, 1909.

[6] Stark, *Ann. der Phys.* (3), 62, p. 353, 1897.

Owing to the high absorption coefficient of metals the rays should therefore be completely absorbed in a thinner layer than is required in lampblack. Kurlbaum found that about 3.5 times as much (by weight) platinum black was required to produce the same absorption as in soot. Evidently not all of the individual particles of platinum black are of the minimum thickness required to avoid reflection, or the material has some property as yet unknown. This is inferred on the assumption that the density and the thickness of the layer of these two materials is the same in the experiment, which was not the case. Evidently further investigations are necessary to decide these questions.

In the foregoing paragraphs we have noticed the most probable causes which are instrumental in producing these two extremes in diffuse reflection. In view of the fact that many of the insulators (optically transparent media, for the visible spectrum) have two types of absorption (reflection) bands in the infra-red, which sometimes fall within the spectral regions examined in the present investigation, it is important to notice the distinction between these two types of bands. For example, a plate of quartz is transparent to the visible spectrum, has absorption bands in the region of 4 μ and a band of metallic reflection in the region of 9 μ. The apparently anomalous condition of a high (diffuse) reflection of the powder, in the visible and at 8.8 μ, and a low reflection at 4.4 μ, is therefore easily explained. For in the region of 4.4 μ the surface permits the formation of "body color," as is true of pigments.[7] In the region of 8.8 μ the high reflection in powdered quartz is owing to the coarseness of the grains. If the grains were as fine as those of platinum black, one would expect the reflecting power in this spectral region to be as low as obtains in platinum black. Similar conditions are to be observed in some of the pigments, (*e.g.*, litharge, yttrium oxide, and chromium oxide).

II. SUMMARY OF PREVIOUS INVESTIGATIONS.

Three methods have been used in determining the amount of energy lost by diffuse reflection from rough surfaces. The first method is based upon the assumption that the diffusion fol-

[7] See Wood's "Physical Optics," New Edition, pp. 441 and 439, "Body Color and Surface Color."

lows the cosine law. The amount of incident energy is measured; also the amount of energy reflected at a given angle from the normal. By integration the total amount is obtained that is lost by diffuse reflection. This method was used by Angström.[8] He used a surface bolometer at an angle of 40°, and found that for a thickly-sooted platinum black surface the reflecting power varied from 0.82 per cent. to 1.25 per cent., being apparently larger for the short wave-lengths. Practically the same method was used by Hutchins.[9] With a radiomicrometer he investigated the cosine law of diffuse reflection of various substances. He found that the diffusion from rough surfaces of such substances as magnesium oxide and plaster departed an appreciable amount from the cosine law for large angles, while for paper this departure was very marked for angles between 20° and 60°. By integration he found the total amount of energy lost by diffusion.

For a white surface "plaster," using sunlight as a source of energy, the integrated value for the reflecting power (the albedo) was 92.7, for paper it was 82.6, and for a green leaf it was 30.2, which values are in fair agreement with the results of the present research.

Another method for obtaining the diffuse reflecting (the absorbing) power is to compare the emission of a heated surface with the emission of a black body which is at the same temperature. This method was used by Crova and Compan.[10] They found that the loss by reflection from the soot of a candle flame varied from 0.68 to 1.25 per cent.; and for a layer of the same washed with alcohol the loss was 3.17 per cent. Kurlbaum[11] used this method to find the absorption (emission) of different thicknesses of electrolytically-deposited platinum black and of soot. For soot the maximum emission of 94.5 per cent. was attained in a deposit containing about 30 mg. per dm.^{2}; but using a thicker deposit of about 100 mg. per dm.^{2}, the emission was only about 88 per cent. of a black body. In platinum black the emission was only about 30 per cent. for a deposit weighing

[8] Angström, Öfversight Af. K. Vetensk. Akad. Förhandlinger, Stodkholm, 55 (No. 5), p. 283, 1898.

[9] Hutchins, *Amer. Jour. Sci.*, 6, p. 373, 1898.

[10] Crova and Compan, *Compt. Rend.*, 126, p. 707, 1898.

[11] Kurlbaum, *Ann. der Phys.* (3), 67, p. 846, 1899.

30 mg. per dm.^{2}. The maximum emission of 96.8 per cent. was attained in deposits weighing about 200 mg. per dm.^{2}, which value remained constant for deposits weighing 300 mg. per dm.^{2}.

He recommended that, for measuring radiations of wavelengths up to 8 μ, it is sufficient to deposit the platinum black for 3 minutes. According to the present method of investigation, in which the platinum black was produced by the same formula as used by Kurlbaum, the deposition of platinum black should be continued for 5 to 6 minutes.

The main objection to this method is that it gives values for the complete spectrum.

A third method is to place the reflecting substance and a radiometer at the conjugate foci of a hemispherical mirror. The incident radiation is introduced upon the reflecting substance by passing through a hole in the centre of the mirror. This method is the easiest to employ; but it requires the determination of several correction factors, which, however, are constant quantities in the investigation. These corrections are (1) the amount of radiation which escapes through the opening in the mirror, and (2) the amount of diffuse radiation which, in its course from the reflecting substance to the radiometer, is absorbed by the silver mirror.

Using this method, Royds [12] carried out a series of measurements under the direction of Paschen. In view of the fact that the present research was well under way when the results of Royds were published, and that the methods differ only in minor but vital points (but that the results are at considerable variance), it is of interest to notice this work in some detail.

Royds used a hemispherical mirror of brass, 5 cm. in diameter. The Rubens thermopile and the blackened strip were placed side by side in the focus of the mirror, and the incident energy (the image of an illuminated slit) was projected on either the strip or the thermopile by means of an external concave mirror. The thermopile did not present a completely opaque surface to the incident radiations, and hence a great amount of the available energy could not be utilized. Moreover,

[12] Royds, *Phil. Mag.*, 21, p. 167, 1911.
Phys. Zeitsch., 11, p. 316, 1910.

the slit image, after reflection from the diffusing surface, may not be very sharp and it may not be uniformly illuminated. This is very marked in the transparent "white" substances, in which much of the light is reflected at considerable distance below the surface, so that the observations must be made upon the assumption that the distribution of the radiation (the "illumination") is the same in the slit image before and after reflection from the diffusing surface. This uniformity of illumination is probably of minor importance for black surfaces; but it is of considerable importance with white surfaces, which may reflect as high as 90 per cent. of the incident energy. Royds makes no mention of having tested his outfit with a white diffusing surface (*e.g.*, magnesium carbonate) which gives a surprising amount of information in regard to the adjustments, the distortion and illumination in the slit image, etc.

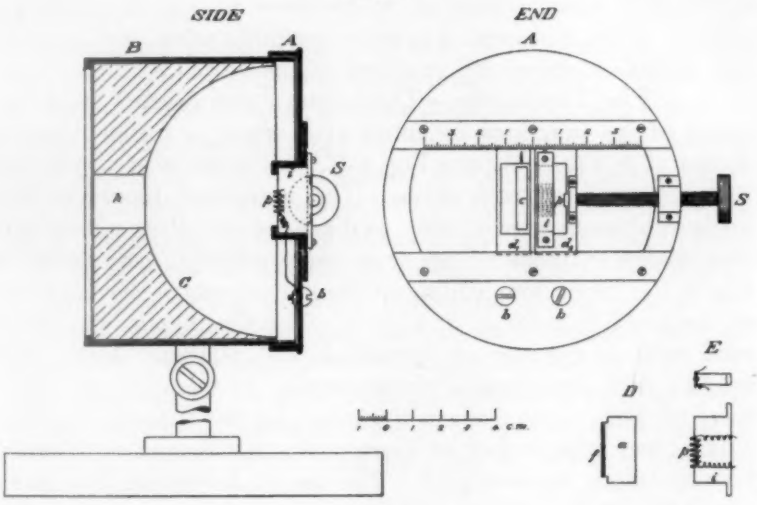
The thermopile and the reflecting surface were stationary, and the image of the illuminated slit was projected upon either one by means of an external concave mirror. This did not permit the use of a cone of rays which filled the opening in the hemispherical mirror. This resulted in a further reduction of the available incident energy, so that in order to be able to measure the small amount of energy which is reflected from lampblack a very sensitive ($i = 0.7 \times 10^{-10}$ ampère) galvanometer had to be employed. As a result, he had to apply corrections for diffuse radiation from the incident image, and for energy radiated from the black surfaces as a result of warming from exposure to the incident radiation. No corrections were made for absorption by the mirror, nor for the opening in the mirror, which correction, he says, could not be estimated. The various corrections to his observations were such that his "apparent" values are two to three times the "true" values. His "apparent" values are usually in fair agreement with results obtained in the present paper.

III. APPARATUS AND METHODS.

In designing the present apparatus, the attempt was made to utilize the maximum amount of the available energy. This permitted the employment of a galvanometer of low sensitivity, which eliminated such corrections as necessarily result when

using a very sensitive radiometer. For example, the correction, used by Royds for the diffuse energy falling upon the thermopile caused by the reflection from air particles when the incident radiation is directed upon the lampblack, was *nil* in the present investigation. The utilization of a large amount of the available incident energy resulted from: (1) the employment of a large hemispherical mirror which permitted the use of a large incident slit image and a large reflecting surface without distortion; (2) the use of a radiometer which intercepted the whole slit image;

FIG. 1.



(3) the use of a beam of radiations which filled the opening in the hemispherical mirror, which was made possible by shifting the thermopile and the diffusing surface, instead of shifting the slit image, as was done by Royds. The main defect in moving the thermopile from its position at the conjugate focus of the reflecting surface (*p*, Fig. 1 A) to the position, *c*, occupied by the reflecting surface, which is necessary in order to determine the intensity of the incident radiation, is the shift of the galvanometer reading owing to differences in emissivity and in temperature in the two positions. This is not marked, however, at the low galvanometer sensitivities used in the work.

The apparatus resulting from the foregoing considerations

proved far more sensitive than was expected, so that for all spectral regions investigated (excepting at 24 μ) the galvanometer,[13] of 5.09 ohms resistance, was used on a complete period of 2 to 3 seconds and a sensitivity of about 1×10^{-9} ampère. For the spectral region of 24 μ the complete period of the galvanometer was from 4 to 5 seconds, the corresponding sensitivity being about 4×10^{-10} ampère.

The ability to use a short-period galvanometer afforded a great saving in time. In fact, the time was consumed mainly in waiting for the optical system to come to temperature equilibrium after mounting a specimen in the hemispherical mirror. This, however, was not a serious matter, owing to the low radiation sensitivity required in the work.

(1) *The Thermopile.*—The bismuth and silver [13] used consisted of 22 junctions mounted in a space 10.5 mm. long, as shown at *p*, Fig. 1 A, and Fig. 1 E. Its width was 5 mm., and its resistance was 10.8 ohms. The individual junctions were made of bismuth wire 0.1 mm. in diameter and silver wire 0.0513 mm. diameter, mounted upon an ivory support, *i*, as shown in Fig. 1 E. The wires leading to the galvanometer were attached to the binding posts *b*, *b*, Fig. 1. The thermopile was blackened with a mixture of lampblack and platinum black, then smoked with soot from a sperm candle. It was covered with a sheet of glass 0.095 mm. in thickness for the spectral region to 0.95 μ; and with a plate of clear rock salt 0.8 mm. in thickness for the longer wave-lengths. The use of a receiver that intercepted the whole slit image eliminated the question of distortion and uniformity of illumination. In the incident slit image the rays are received in practically a normal direction upon the thermopile. In the slit image, formed from the rays reflected from the diffusing surface, the rays fall upon the thermopile at all angles of incidence. The only assumption which is made is that the difference in the loss by reflection from the thermopile and the window is negligible in these two measurements.

(2) *The Hemispherical Mirror.*—The diameter of the hemispherical mirror, which was made of glass, was 10 cm., and the opening for admitting radiation upon the thermopile was 10 by 20 mm.

[13] *Bulletin Bureau of Standards*, 9, p. 7, 1912.
JOURNAL FRANKLIN INSTITUTE, Dec., 1911.

The arrangement of the mirror in the mounting is shown in Fig. 1 B. The support for the thermopile and the substance to be investigated was mounted upon a movable stage, *d*, *S*, which in turn was mounted upon a brass plate which was provided with a wide flange (Fig. 1 A). By slightly tilting this brass plate, *A*, upon the support, *B*, it was possible to focus the slit image of the radiations reflected from the diffusing surface, *f*, Fig. 1 D, upon the thermopile, *p*. This adjustment of focus was necessary for specimens which did not fit nicely in the place occupied by the brass block, *a*, upon which the substances, *f*, were usually mounted.

The distance (6 to 7 mm.) between the incident slit image, upon the surface, *c*, and its reflected image upon the thermopile (*p*, Fig. 1 A) was made as small as possible in comparison with the size of the hemispherical mirror. Previous tests with a Nernst glower 10 mm. long showed no distortion of the image of the glower for a displacement of 1.2 cm. from the axis of the mirror. However, in the slit image of the light reflected from the diffusing surface the illumination did not appear so uniform, and there appeared to be more aberration at the ends of the slit image. This was especially marked in a cleavage piece of marble, from which the reflected slit image was surrounded with a hazy illumination. A piece of white cardboard with an opening 5 by 10 mm. was placed over the thermopile. This facilitated in focusing, and in determining that all the diffusely reflected light fell upon the thermopile.

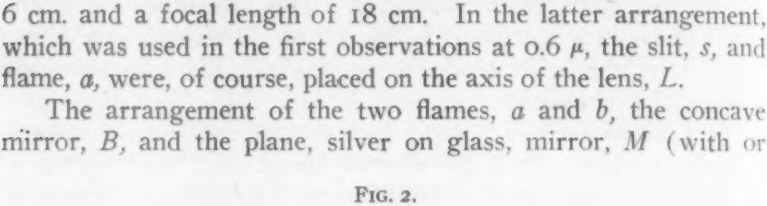
These adjustments were made with a white diffusing surface (of Al_2O_3 or $PbCO_3$) of the same thickness as the lampblack surfaces, which, owing to its high reflecting power, produced a bright slit image. In this manner the effect of change in focus upon the amount of radiation falling upon the thermopile was investigated.

(3) *The Optical System.*—The arrangement of the optical parts of the auxiliary apparatus is shown in Fig. 2, which shows the hemispherical mirror, *A*, containing the reflecting substance, *f*, and the thermopile, *p*. The cylindrical acetylene flame was at *a*, and the Bunsen flame, or Welsbach mantle, was at *b*. The shutters, *d* and *e*, were made of thin sheet aluminum (10 by 15 cm.), with an intervening layer of asbestos about 3 mm. in thickness. They were bright on the front side, and painted black

on the side toward the thermopile. A large, water-cooled diaphragm, with an opening 5 cm. in diameter, was placed at *C*. A flame placed back of a large plate of sheet iron, with a slit, *s*, represented the source of energy. An image of this slit was projected into the hemispherical mirror by means of a large concave mirror, *B* (17 cm. diameter, 100 cm. focal length), or by means of a triple achromatic lens, *L*, having a diameter of 6 cm. and a focal length of 18 cm. In the latter arrangement, which was used in the first observations at 0.6 μ, the slit, *s*, and flame, *a*, were, of course, placed on the axis of the lens, *L*.

The arrangement of the two flames, *a* and *b*, the concave mirror, *B*, and the plane, silver on glass, mirror, *M* (with or

FIG. 2.



without an absorption cell, *c*), as shown in Fig. 2, permitted the measurement of the radiations at 0.65, 0.95, and 4.4 μ, in succession, before changing a specimen. For isolating the radiations at 8.8 μ two quartz plates, 5 mm. in thickness (ground and blackened on the rear side), and the silver mirror, *M'*, were placed as shown at Q_1 and Q_2. Two fluorite plates were placed at Q_1 and Q_2, respectively, for isolating the radiations at 24 μ. The proper positions of these mirrors were obtained by focusing with silver on glass mirrors at Q_1 and Q_2 respectively.

The beam of light did not entirely fill the opening, *h*, in the hemispherical mirror, so that by slightly turning the mirror, *B*, about a vertical axis it was possible to change the angle of incidence of the radiations, and project them upon different parts

of the reflecting surface, *f*, which usually was about 6 mm. wide, and from 12 to 20 mm. in length.

The material to be examined was usually melted upon a brass block (*a*, Fig. 1 D), which was 25 by 6 by 10 mm., which was inserted in the opening, *c*, in the stage, d_1, Fig. 1.

The arrangement of the shutter, *d*, and the gas mantle, *b*, at a distance of about 15 cm. from the slit, *s*, Fig. 2, prevented the latter from becoming warm and radiating upon the thermopile, which would happen when the water cell, *c*, was not in place. When the gas mantle or the Bunsen flame was used (for radiations at and beyond 4.4 μ), the acetylene was, of course, extinguished, the shutter, *e*, was kept raised, and the absorption cell, *c*, was removed.

When using the triple achromatic lens for projecting the slit image, the size of the opening in the sheet of metal, *s*, which formed this slit, was 1.5 by 7.5 mm., and the image was practically the same size. Owing to the large angle of incidence there was some astigmatism in the image produced by the concave mirror. The slit was therefore reduced to 7 by 2 mm., and finally to 7 by 1.5 mm. In all cases the image of the slit at *f* was about 8 by 2 mm., hence there was no danger of the radiations falling outside of the thermopile, especially after reflection at *f*, and refocusing at *p*, Fig. 2, when the slit image was not very sharp.

The method of determining the reflecting power consisted in observing the galvanometer deflection when the radiations were projected upon the specimen at *f*, and after reflection therefrom were focused upon the thermopile at *p;* then, moving the stage, *S*, Fig. 1, until the thermopile occupied the position of *f*, in observing the galvanometer deflection for the direct slit image. The ratio of the reflected radiations to the direct radiations (in galvanometer deflections) gives the reflecting power. The observations were duplicated for most of the substances. This is especially true for the radiations at 0.65 μ, where the triple achromatic lens and also the concave mirror arrangement were used for projecting an image of the slit upon the substance; also for the radiations at 0.95 and 4.4 μ, using the concave mirror for projecting the slit image. In the final work many of the original observations were repeated at 0.95 μ and 4.4 μ (using the two flames and shutters, as already described) before remov-

ing the specimen. Throughout the work the various specimens were kept covered to prevent the deposition of dust.

(4) *Regions of the Spectrum Examined.*—The reflecting power of various substances was found for the following regions of the spectrum.

(1) That part of the radiation of an acetylene (cylindrical) flame which is transmitted through a 1 per cent. solution of cupric chloride,[14] 2.5 cm. in thickness. Such a solution is opaque to all radiations lying beyond 0.7 μ. The energy curve of this transmitted radiation does not differ markedly from the solar energy curve. The maximum of the transmitted energy lies at 0.6 μ.

(2) That part of the radiation from an acetylene flame which is transmitted by a 1 per cent. solution of cupric chloride 2.5 cm. in thickness and a plate of green glass 2.5 mm. in thickness. The transmitted radiation is fairly monochromatic, the maximum being at 0.54 μ.

(3) The radiation of an acetylene flame which is transmitted through a 2 cm. layer of water. The water cell transmits uniformly all the visible and part of the infra-red to 1.4 μ. The maximum of the energy curve of the transmitted radiation lies at 0.95 μ. By using a plate of red glass 2.15 mm. in thickness, as indicated in the tabulated data, the radiations are more homogeneous, extending from 0.67 μ to 1.4 μ.

(4) The radiation from a Bunsen flame, which consists of a small emission band at 2.7 μ and a very strong band at 4.4 μ. About 90 per cent. of the energy emitted by a Bunsen flame lies at 4.4 μ.

The purity of the maximum emission was tested with a thick plate of glass which is opaque to radiation lying beyond 3.5 μ. A sheet of plate glass 8 mm. in thickness transmitted 5.8 per cent., and a sheet 15 mm. in thickness transmitted 3.7 per cent. of the radiation from the flame. From this it appears that the homogeneity of the Bunsen flame radiation at 4.4 μ is not seriously affected by the weak radiations at 1.9, 2.7, and 5.3 μ.

(5) The residual rays from quartz. The source of energy was the radiation from a Welsbach mantle which was reflected from two surfaces of quartz, which has two intense bands of

[14] *Bulletin Bureau of Standards*, 7, p. 619, 1911; also 1912.

selective reflection, at 8.50 and 9.05 μ, respectively. The mean of the energy curve is at 8.8 μ. The maximum of this radiation was very homogeneous, only 0.43 per cent. of the total radiation being transmitted by a glass plate 1.5 mm. in thickness. The glass plate transmitted radiations to 4.5 μ, beyond which point, up to 8 μ, the reflecting power of quartz is extremely low; and throughout this region of the spectrum the radiation from the gas mantle is very weak.

(6) The residual rays from fluorite. The source of energy was an incandescent gas mantle, reflected from two plates of fluorite. The maximum of the energy curve was fairly homogeneous, 1.5 per cent. being transmitted by glass (opaque beyond 4.5 μ) and 7.8 per cent. being transmitted by a plate of fluorite 1.5 mm. in thickness, which is opaque beyond 10 μ. The homogeneity could have been increased by adding another reflecting surface of fluorite; but it would have been at a sacrifice of the total energy available. Most of the black reflecting surfaces examined increase in reflecting power with wave-length. Hence, it is to be inferred that the observed values would be a trifle higher than here observed if the radiation had been more homogeneous. This is of minor importance, owing to the variation in reflecting power of samples of the same substances. The thermopile was covered with a plate of rock salt, 0.8 mm. in thickness, which is opaque to radiations beyond 30 μ; hence, the maximum of the residual rays is shifted from its true position to about 24 μ.

(5) *Corrections to Observations.*—A part of the energy reflected from the substance under examination escapes through the opening which admits the radiations into the mirror. The amount of energy thus lost was determined experimentally by covering, temporarily, a part of the silvered surface adjoining the opening by means of a thin sheet of aluminum blackened in an acetylene flame. The aluminum sheet was bent to fit the curvature of the mirror, and the area of the blackened surface was 10 by 20 mm. When not in use this blackened surface was withdrawn through the opening in the hemisphere. The experiment consisted in noting the amount of energy (in galvanometer deflections) reflected from a layer of lead carbonate *with* and *without* the blackened surface in place within the hemisphere. The ratio of the galvanometer deflections in four

complete series of observations varied from 97.1 to 97.5 per cent., with a mean value of 97.3 per cent. On the assumption that, in the region occupied by the black surface, the illumination differs by a negligible amount from the value for the centre of the

TABLE I.

REFLECTING POWER OF LAMPBLACK.

Wave-length. λ max.	.54μ	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%	%
Silver	93.2	89.9	93.4	94.6	98.0	98.0	98.5
Aluminum		68.5			92.3		
Correction factor	1.102	1.143	1.100	1.086	1.049	1.049	1.043
Lampblack Paint		2.94			3.24		
		3.02			2.29		
		3.58			3.60	Alcohol + shellac.	
		3.72			4.86		
		3.10	3.38	3.36	3.34	3.75	4.4
Paraffin candle (hot)			0.97				
(Cold soot)		1.07 1.43					
Rosin			1.26		1.31		
					.85	1.07	2.8
Sperm candle			.91		.67	1.44	3.9
			1.02		.93	1.27	4.1
			1.25		1.03		
			1.07		.77	1.28	
			1.01		1.36	1.23	
					1.28	.87	
Camphor (Paint)			1.34		1.38	1.46	
			1.30		.95	1.65	5.7
			1.36		1.15		
			2.80		3.24		
Acetylene			.59				
			.82		.92	1.12	3.0
			.64		.71	1.24	
			.54		.81		
			.42		.71		
(Cold deposit)			.86				
(No air)			1.33				

mirror, the amount of energy lost by escaping through the opening is about 2.7 per cent. of the total energy diffusely reflected within the hemisphere.

A further correction is necessary for the absorption of the diffuse radiations by the silvered surface of the hemispherical mirror. This correction, which depends upon the spectral region

observed, was determined by placing a newly silvered plane mirror in the place occupied by the diffusing surface, *f*, Fig. 2, and at *c*, Fig. 1 A. This plane mirror was placed at the proper angle to reflect all the incident energy upon the interior of the hemispherical mirror and from thence upon the thermopile. The ratio of the galvanometer deflection for the energy reflected from the silvered surface, to the deflection for the energy falling directly upon the thermopile, gave the reflecting power of the two silver surfaces, and the square root gave the value sought for a single reflecting surface. These values of the reflecting power, determined by this method, are in excellent agreement with the values obtained by the methods previously employed by other observers. The values of the reflecting power of silver, for the spectral regions employed, are given in Table I. In this same table are given the complete correction factors with which the observed (the "apparent") reflecting power of the various substances was multiplied in order to obtain the "true" (the absolute) values recorded in these tables. These factors are the reciprocals of the products obtained by multiplying the reflecting power of silver by the per cent. of diffuse energy (97.3) which is intercepted by the hemispherical. The silvered surface, being well protected, does not tarnish, so that these correction factors are constant for the investigation.

The corrections used by Royds, viz., (1) the correction for extra radiation falling upon the thermopile, as the result of scattering by air and dust particles when the incident radiation was projected upon the diffusing surface, and (2) the correction for re-radiation upon the thermopile, as a result of warming of the diffusing surface by the incident radiation projected upon it, were *nil* in all cases, except when very thick (0.3 to 0.4 mm.) layers of lampblack were examined. The thick lampblack surfaces seemed to become heated when they appeared to radiate upon the thermopile. To the eye they were just as black as thin deposits of (acetylene) soot. Nevertheless, they apparently reflected from 2.5 to 2.8 per cent. at 0.95 μ and 4.4 μ, and 8 to 12 per cent. at 8.8 μ. A thin deposit of soot which appeared equally black, and examined at the same time, would reflect less than 1 per cent. The lampblack paints also reflected about 3 per cent., and they appeared very much lighter (reflected more of the incident radiation upon the thermopile, as could be

observed visually) than the soot deposits. To prevent radiations of the heated thick films of soot from falling upon the thermopile, a thin (0.09 mm.) sheet of glass was placed over (and about 1 mm. from the surface of) the deposit of soot. The reflecting power of the thick layer at 0.95 μ was then reduced from 2.7 per cent. to 1.08 per cent., which is about as low a

TABLE II.

REFLECTING POWER OF PLATINUM BLACK.

Wave-length. λ max.	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%
Chemically precipitated paint	2.01	2.92		6.00		
		2.43	2.50			
			2.53	5.76	8.67	12.1
Platinum black and lampblack paint	2.77	2.70	2.84	4.02 3.94	6.44	8.2
Platinum black and soot	1.46	1.38				
Electrolytic:						
No. 4		1.22		8.8	13.2	
No. 5		9.8		2.64	4.63	
"		1.16		2.68		
No. 14, 1 minute					25 to 30	
No. 13, 2 minutes					11.3	
No. 9, 3 minutes					5.9	
No. 10, 3 minutes		.99		1.72	3.66	7.5
No. 11, 4 minutes				1.54	2.40	4.4
" "		1.16		1.59		
No. 12, 5 minutes		1.12		1.50	1.84	3.9
No. 16, 5 minutes		.85		1.48	2.71	
No. 15, 6 minutes		1.01		1.51	2.23	3.4
No. 18, 6 minutes				1.33	1.78	
" "		1.08		1.35		
No. 19, 6 minutes					2.13	
No. 19 and soot				.93	1.27	4.1
" "		1.25		.99		
No. 17, 7 minutes		.98		1.44	1.82	3.3
No. 20, 7 minutes				1.29	1.88	2.9
" "		.97		1.31		

value as observed on a thinner film in which the conductivity to the brass block was effective. It was evident that the high reflection was caused by re-radiation, and no attempt was made to examine very thick films such as used by Royds. The thickness of the deposits of soot was of the order of 0.1 mm., which by experiment was found sufficient to absorb the maximum amount of radiation. The presence of stray radiations was also

tested. To this end the reflecting surface (brass block) was removed from the carrier, *d*, Fig. 1, and the radiations coming through the opening, *h*, in the hemispherical mirror were permitted to pass out through *c* to the rear of the apparatus and fall upon a piece of black velvet. This test was applied at various times in the different spectral regions used and at various galvanometer sensitivities, but no deflection (as large as 0.1 mm.) could be observed which was caused by radiations scattered by air and dust particles. The galvanometer could be read to 0.1 mm. The smallest deflections, observed by reflection from the blackest surfaces, were from 8 to 10 mm., and usually they were much larger. Hence, if there had been corrections such as observed by Royds, they could not have escaped notice. As mentioned elsewhere, the apparatus was designed so as to require a low radiation sensitivity which eliminated these corrections, and the accuracy which one could easily attain was 1 part in 200 to 400. Evidently, from the nature of the material, it would have been illusory to attempt a higher accuracy. As an illustration of the accuracy attainable on a low reflecting power substance, the value for platinum black (No. 16, Table II) may be cited. Two determinations on different days gave respectively 2.71 and 2.75 per cent. for the reflecting power.

IV. REFLECTING POWER OF LAMPBLACK.

The experimental results obtained in this research may be briefly portrayed by means of tabulated data and by brief comments relating thereto. As found by others, all sorts of lampblack (soot) surfaces can be prepared, differing in reflecting power, for the same flame and for different flames. The most permanent coatings are, of course, layers of paint made by mixing lampblack with turpentine, or, if the latter dries too slowly, with turpentine and alcohol. A weak alcoholic solution of shellac gives a much more grayish appearance to lampblack, as shown by the highest values obtained in Table I. But the reflecting power of the paint is so high that it is a question whether it might not be better practice to resmoke radiometers when the soot comes off.

Owing to the fact that many of the soot deposits became soiled before they could be examined in another spectral region,

and also to the fact that in any given spectral region various deposits of soot were examined, when they were removed from the brass blocks to be replaced by others, but few of the same deposits were examined in more than two or three parts of the spectrum. Hence (for clearness), Table I differs from the other tables in that the observations of reflecting power upon the same film, in different spectral regions, are joined by dotted lines. The additional observations in any spectral region, *e.g.*, sperm candle, at 8.8 μ, are recorded without any special reference to the other observations.

Various experiments were performed on lampblack paints prepared from commercial lampblack. The best (purest) material gave reflecting power varying from 2.9 to 3.1 per cent. at 0.60 μ. This is in agreement with results obtained by depositing soot from burning camphor in a "watch crystal" and working it into a smooth paint with turpentine. As shown in Table I, the reflecting power of lampblack paint is fairly uniform in the region of 4 to 8 μ, and a fair correction factor for diffuse reflection from a radiometer is from 3.3 to 3.5 per cent.

Finely-ground boneblack, although having a very brownish color, becomes quite black ($R =$ about 1.5 per cent.) when the turpentine has not thoroughly dried. From this it would appear that if the proper vehicle could be found it might be a much darker paint than ordinary matte lampblack paint.

The deposits of soot from the different flames were "hot" when the brass block was drawn through the flame or "cold" when the flame was cooled by a sheet-iron funnel, with an opening 1 by 10 mm. at the top, through which the smoke issued, and over which the brass block was held. The cold deposits usually had a higher reflecting power than the hot deposits. As already mentioned, layers 0.05 to 0.1 mm. in thickness usually produced a maximum absorption. Thicker films produced higher values for the reflecting power, owing to heating of the surface as the result of lack of conduction to the brass block, which then radiated upon the thermopile.

Some of the samples of soot appeared to have a slightly higher reflecting power in the visible than in the infra-red, as was shown by repeated measurements upon the same film. In the case of the deposit of soot (from a sperm candle) upon the layer of platinum black, No. 19, Table II, the reflecting power is

considerably higher at 0.95 μ than at 4.4 μ. Whether this is owing to the structure of the material, depth of penetration (which is a function of the wave-length), and consequent variation in conductivity, is unknown. It does not appear unreasonable to suppose that, for visible radiations which do not penetrate deeply, the surface might become hotter (hence re-radiation to the thermopile) than it would for the same amount of energy of wave-lengths at 4.4 μ, which penetrates more deeply into the layer of soot, hence is absorbed nearer the brass surface where conditions are more favorable for heat conductivity. It so happened that for the spectral regions of 0.95 μ, 4.4 μ, and 8.8 μ the incident radiation was of practically the same intensity.

In all cases the blackest obtainable deposits of any given source were investigated. The paraffin candle was discarded because of the difference in the boiling points of its constituents. The deposits were usually whitish. The rosin was burned in a sperm candle; and it, as well as camphor (which burns without the presence of other ingredients), tends to give granular brownish deposits having a reflecting power of about 1.3 per cent. in the visible spectrum. The "cold" deposits from a standard candle are fairly uniform, reflecting about 1.25 per cent. The "hot" deposits are much blacker and reflect about 1 per cent. Viewed at grazing emergence, the surfaces appear as smooth as polished mirrors.

The blackest obtainable "hot" deposits are made in the acetylene flame, the lowest observed reflecting power being 0.42 per cent., and the average deposit reflecting about 0.6 per cent., at 0.6 μ. The "cold" deposits, obtained by holding a piece of sheet iron against the flame and allowing the resultant smoke to deposit upon the brass block, give somewhat higher reflecting powers, which are of the order of 0.8 per cent. None of these deposits have the brownish appearance to be observed in all deposits of soot from burning camphor. All these deposits were obtained by using standard burners. To test the effect of combustion without air being mixed with the gas before ignition, a glass tube was drawn down to a point which then formed the "burner." The flame emits, of course, a dense cloud of smoke. The deposit upon the brass block was smooth and brownish in color, similar to camphor soot. The reflecting power (see

Table I, Acetylene, "no air") was 1.33 per cent., which is the average value of camphor soot.

In a previous paper,[15] which gives data on the absorptivity of an acetylene flame, attention was called to the peculiar selective absorption band in the visible spectrum, which was similar to bands found in metals, *e.g.*, nickel and platinum, which are in a colloidal state. Moreover, in the beginning of this paper attention was called to the seemingly colloidal properties of platinum black. Platinum black and acetylene soot are the blackest substances yet recorded; and of these the acetylene soot has the greater absorption. It is not unreasonable to consider the carbon particles (and the platinum in the electrolyte) to be in the colloidal condition, at the instant of disruption of the gas molecule. In the hottest part of the flame one obtains the finest particles, *i.e.*, the blackest surfaces. These surfaces, viewed at grazing emergence, appear as perfect mirrors, having a high reflecting power.

Acetylene soot has a very low heat conductivity which permitted warming of the superficial layers of a thick deposit of soot. The temperature rise was sufficient to cause re-radiation upon the thermopile, and, as explained elsewhere in this paper, the apparent reflecting powers at 4.4 to 2.4 μ were of the order of 2.6 to 3 per cent., when an equally black thin film reflected less than 1 per cent. By placing a thin sheet of glass in front of the thick film (this was possible for the region of 0.95 μ without disturbing the adjustments) which absorbed all the radiations of long wave-lengths, the reflecting power was reduced from 2.6 per cent. to 1.08 per cent., showing that the high value was erroneous. In practice a radiation instrument should, therefore, be covered with a film of acetylene which is less than 0.15 mm. thick.

The blackest deposits of soot are obtained by holding the metal plate in the flame. But this will be rarely possible with radiation instruments. Furthermore, unless one constructs a special burner, it is not possible to blacken large surfaces in the flame without having them streaked with grayish-colored material. One must, therefore, use cold deposits and standard material. The standard sperm candle is the most promising source, the reflecting power of the blackest surfaces being about

[15] *Bulletin Bureau of Standards*, 7, p. 243, 1911.

1 per cent., in the visible spectrum, which is the order of accuracy of radiation work at the present day. It is difficult to remove fine dust from these surfaces, hence it appears advisable to use a hemispherical mirror to intercept the diffusely reflected rays.

For the absorbing surface of a secondary radiometer which has been calibrated against a primary standard it seems desirable to use the best quality of lampblack paint, the vehicle being a volatile turpentine. If the turpentine has polymerized and dries slowly, then a mixture of turpentine and alcohol should be employed. The turpentine is, of course, used simply to render the lampblack adhesive, and it is used instead of a dilute alcoholic solution of shellac because, as already mentioned, the latter tends to produce a grayish surface. All these surfaces are, of course, perfectly matte. The lampblack paint is easily freed from dust, hence is to be preferred to soot when the instrument must be operated in the open air.

V. REFLECTING POWER OF PLATINUM BLACK.

The electrolytic deposits of platinum black were deposited upon sheet platinum 0.02 mm. in thickness and 0.5 by 4 to 5 cm. in area. These platinum sheets were then mounted upon the brass blocks, already described, by means of Khotinsky cement. The first surfaces were made from a solution of platinum chloride, which usually gave grayish deposits. After many attempts, which included Nos. 4 and 5, Table II, a new solution of chloroplatinic acid was prepared by dissolving a known weight of platinum (4 Gr. of sheet platinum) in aqua regia. This material was evaporated to as near dryness as possible over a water-bath. This evaporation process was repeated after adding hydrochloric acid. The resulting material, which is a thick, reddish syrup, contained 8.3 Gr. (theoretical value) of H_2PtCl_6. From this a solution of the proper concentration recommended by Kurlbaum [16] was made up, viz., 5 Gr. of H_2PtCl_6, 150 Gr. of water, and 0.04 Gr. of lead acetate. The deposits of platinum black were made by passing a current of 0.03 ampère per cm.^{2} of exposed surface, the time being varied from 1 to 7 minutes. By occasionally jarring the electrodes the escape of gas bubbles was prevented. This procedure seemed to assist in

[16] Kurlbaum, *Ann. der Phys.* (3), 67, p. 846, 1899.

forming black deposits. The cathode (strip to be blackened) was, of course, placed between two strips of platinum, which formed the anode. The distance between the anode and cathode was about 2 cm. The platinum strips were made sufficiently long and every other precaution was taken so as not to contaminate the solution by acting upon the copper leads.

The manner in which the reflecting power decreases with increase in thickness of the deposit is well illustrated in the samples, Nos. 14 to 20, given in Table II. The reflecting power is a function of the wave-length, a much thinner deposit being required to produce a maximum absorption for the spectral region of 4.4 μ than for the region of 8.8 μ. At normal incidence the thin deposits appear darker and more velvety than the thick ones, but a slight deviation from the normal increases the reflecting power, as illustrated in No. 4 at 8.8 μ. Moreover, some of the very dark, velvety, thick deposits tend to give high values beyond 4.4 μ, although they show an abnormally low reflection in the visible spectrum. This was definitely determined by repeated tests on No. 16, which was similar in appearance to No. 17. To the eye No. 16 appeared slightly darker than No. 12. The deposits Nos. 18 and 19 were on the opposite sides of a strip of platinum, deposited at the same time. The reflecting powers (1.78 and 2.13 per cent. respectively) are considerably different at 8.8 μ. Of course, this is quite a severe test of reproducibility. Deposits that were continued for more than 7 minutes became rough and nodular. From Table II it may be noticed that the deposition of platinum black should be continued for at least 5 minutes to obtain a maximum absorption at 4.4 μ; and the best practice is to continue the process 6 to 7 minutes, when the maximum absorption is attained at 8.8 to 2.4 μ. The reflecting power then rises gradually from about 1 per cent. in the visible to 3 per cent. at 24 μ.

The deposits are quite adhesive, so that if kept free from dust the reflecting power changes but little with age. This is illustrated in the two series of measurements on Nos. 18 and 20 at 4.4 μ, which were re-examined after an interval of about a month, when the apparatus was entirely readjusted and different-sized slit images were used. The ever-present particles of lint were first removed by blowing gently with the breath. In the second set of measurements on Nos. 18, 19, and 20 the observa-

tions at 0.95 μ and 4.4 μ were made in succession before removing the specimen. It is, of course, to be understood that, owing to the labor involved in making the adjustments of the quartz and fluorite plates, the regions of 8.8 μ and 24 μ were examined separately. Hence, the specimens were all examined in succession at 8.8 μ before turning to the region of 24 μ.

The deposit No. 19 was smoked with soot from a sperm candle which raised the reflecting power in the visible spectrum without materially affecting the region of 4.4 μ.

Chemically-precipitated platinum black was also examined. It is quite brownish in appearance. One of the three samples was a layer of the material pressed upon the brass block, as already described. The others were painted on the brass plates by means of a solution of alcohol and turpentine, which dries quicker than turpentine. In both cases the reflecting power is high (2 per cent.) in the visible, increasing to 12 per cent. at 24 μ. This is owing to the property of the material and not to the thickness of the layer. The thickness of the layer in the various samples examined varied from 0.1 to 0.3 mm. By mixing lampblack and platinum black, equal parts (by bulk), and applying it as paint, the reflecting power is raised in the visible and reduced at 24 μ. This specimen was then covered with soot and the reflecting power was reduced to about 1.4 per cent. Although the reflecting power is now more uniform throughout the spectrum, it is not more so than the electrolytic deposit, which reflects only about one-third as much energy. Hence, the precipitated material, or mixtures of the same, is less desirable than the best obtainable lampblack paints (see Table I).

In lampblack, difficulty was experienced in making measurements, owing to re-radiation which resulted from the low heat conductivity and consequent heating of the thick layers of soot. This was not experienced in platinum black, owing to better thermal conductivity. The glass window over the thermopile absorbed this re-radiated energy from the black surfaces. In the case of platinum black (which was more thoroughly studied than soot because it gives more permanent surfaces), the reflecting power at 0.95 μ was determined with a glass and with a rock-salt window on the thermopile. The values are in perfect agreement, showing that there was no re-radiation upon the thermopile when the rock-salt window was used. The values

are, therefore, to be considered reliable, and the slight variations in the reflecting power observed in the table are owing to differences in the structure of the deposits. Even with the new solution one of the deposits came out quite grayish in appearance. This seemed to have been caused by excessive agitation of the electrolyte to keep the electrodes free from the stream of gas bubbles.

An examination of six commercial surface bolometers (twelve branches, or 24 surfaces) showed that all the herein-described deposits of platinum in which the deposition of platinum black was continued for at least 4 minutes were better than the surface of the best bolometer on hand. The bolometer surfaces (even the thick deposits) showed bright spots where the metal was exposed. One bolometer had a thin deposit, similar to the 1 to 2 minute deposits shown in Nos. 13 and 14, Table II. From this the conclusion is to be drawn that the correction for diffuse reflection from a commercial surface bolometer is from 2.5 to 3 per cent., or perhaps as high as 5 per cent. In fact, with the improved facilities now at hand it is better to obtain new data on the total radiation of black bodies, rather than attempt to correct the old data, which are now of historical interest.

With this end in view, now that the present research is completed, it is purposed to use the knowledge gained, as well as the hemispherical mirror and thermopile, in obtaining data on the constants which enter the Stefan law of total radiation.

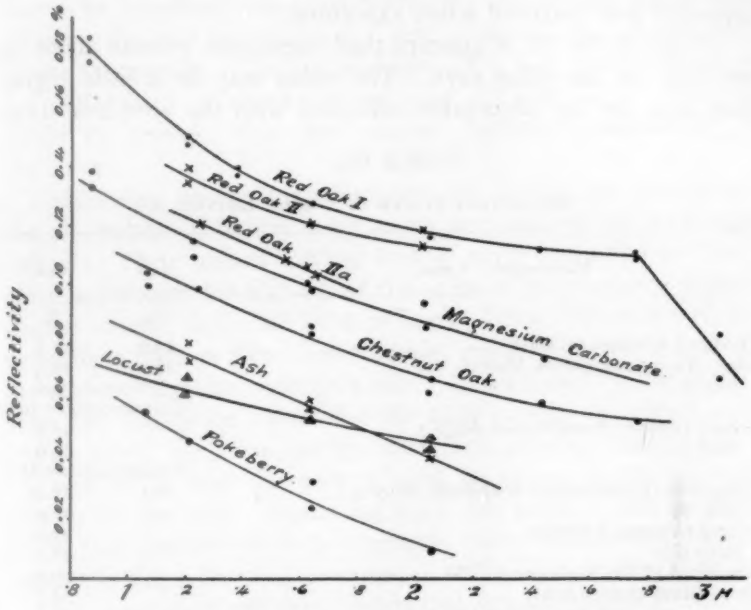
VI. THE REFLECTING POWER OF GREEN LEAVES.

The first examination of diffuse reflecting power of growing leaves was undertaken in May, 1908, the apparatus employed being a bolometer, a mirror spectrometer, and a fluorite prism. The leaves were mounted upon a holder beside a silver comparison mirror, and the observations were carried out in the same manner as was employed in the determination of the reflecting power of plane mirrors.[17] The angle of incidence was 45°, and the distance of the reflecting surface to the spectrometer slit was about 6 cm. The source of light was a Nernst

[17] *Bulletins Bureau of Standards*, 2, p. 457, 1906; 7, p. 197, 1911.

glower. The values thus obtained are, of course, only relative for the different wave-lengths. The observations extended to 3 μ (see Fig. 3), and in all cases there appeared to be a decrease in the amount of energy reflected with increase in wave-length. This seems plausible, for the increase in opacity with wave-length beyond 1.4 μ, which obtains in water, would decrease

FIG. 3.



Reflecting Power of Green Leaves.

the amount of radiation that can return by internal reflection. The curve "Red Oak, II *a*," was obtained after the sample "Red Oak, II," had remained upon the spectrometer over night, when considerable of the moisture had evaporated. It is, therefore, to be expected that the reflecting power would be less than when the cells contained moisture.

In the case of magnesium carbonate, the decrease in reflecting power with increase in wave-length might result from a decrease in refractive index, which obtains in all similar "trans-

parent media." This decrease in reflecting power is more noticeable in the region of 4.4 μ.

In this year's work, unless otherwise noted, the green leaves were examined in the latter part of May. The oldest (darkest green) leaves were selected, which were entirely free from injury. The reflecting power is somewhat less for the fully-matured leaves of the oak and the tulip tree (Table III), gathered in July. The clover, locust, laurel, and lilac leaves appeared well matured when examined.

From Table III it appears that vegetation reflects about 25 per cent. of the solar rays. The value may be a little higher than this, for the absorption cell used with the acetylene flame

TABLE III.

REFLECTING POWER OF GREEN LEAVES.

Wave-length. λ max.	.54μ	.60μ
	%	%
Clover (*Trifolium pratense*)	23.9	21.3
Lilac (*Syringa vulgaris*), May 3	26.0	25.3
June 8		23.6
		(Transmission = 19.6)
Locust (*Robina pseudacacia*), May 3		25.4
June 8		23.9
		(Transmission = 20.7)
Tulip tree (*Liriodendron tulipifera*), May 3	28.1	27.2
July 29		22.0
Laurel (*Kalmia latifolia*)		23.2
Rear side		27.7
Basswood (*Tilia Americana*)		26.9
Elm (*Ulnus Americana*)		25.7
Oak (*Quercus rubra*)—Young leaf		29.3
Dark green		21.8
Mullein (*Verbascum thapsus*)		24.2

produces an energy distribution which is somewhat richer in red and infra-red rays than obtains in average sunlight. This value cannot greatly differ from the true one, however; for, using monochromatic radiation corresponding closely with the color of leaves (green glass; $\gamma = 0.54\ \mu$), the observed reflecting power of clover, lilac, and tulip leaves is not much higher than for the composite rays, which have a maximum at 0.60 μ. These tests were, of course, applied on the same leaf by simply placing a green glass before the absorption cell. The mullein leaf gave

surprising results; the reflecting power differing but little from that of other leaves. Because of the densely woolly surface, the expectation was to observe a high reflecting power. Evidently the tomentous covering contributes but little in raising the reflecting power. This is of interest in connection with desert plants having a woolly covering. The transmission was difficult to observe, owing to the warming of, and the consequent re-radiation from, the leaves upon the thermopile. The leaf to be examined was placed over the thermopile, the distance between the two being about 1 mm. to avoid heat conductivity to the thermopile. The transmission of a leaf (after correction for reflection) is about 20 per cent. (Table III). The two kinds of leaves, lilac and locust, differed considerably in thickness.

According to the measurements of Brown and Escombe,[18] the absorption of leaves is 68 to 69 per cent. of the total solar energy. Their values for the loss of solar radiation by transmission through the leaf are of the order of 30 per cent., depending, of course, upon the kind of leaf. These values are in fair agreement with present observations, considering the nature of the material and the apparatus used. Brown and Escombe (*l.c.*) have also published values for the total energy expended in internal work, viz., the energy used for photosynthesis (about 1.5 per cent.) and the energy used in transpiration of water (10 to 60 per cent., depending upon the kind of leaf). They found that the maximum temperature excess above its surroundings, to which a leaf can be raised in still air, is about 0.02°.

All these data are very instructive when compared with the reflecting power of building material, *e.g.*, brick, marble, granolith, and asphalt, given in Table V. In the latter the energy absorbed is not utilized in internal work, and the temperature rises a very considerable amount, depending upon exposure to wind, etc. Hence, in marked contrast with vegetation, when the sun is obscured or has set, the building material continues for some time to re-radiate the energy absorbed during the daytime.

It is beyond the scope of this paper to discuss the economic importance which would result from the application of these

[18] Brown and Escombe, *Proc. Roy. Soc., Lond.*, B, 76, p. 29, 1905.

data. Suffice it to say that until traffic demands the full width, a considerable portion of the total width of a street and sidewalk should be occupied by trees and grass, instead of asphaltum and granolith. The reflecting power of a green leaf, in different spectral regions, is given in Table V.

VII. REFLECTING POWER OF PIGMENTS.

The powdered material was mounted upon the brass block (Fig. 1 D). In some cases the material was moistened with water containing a trace of gum arabic; but there was difficulty in causing the material to adhere to the block. This difficulty was overcome by putting a thin coat of shellac varnish upon the brass block. After the shellac had become quite dry a thick (0.3 mm.) layer of the powder was pressed upon the block and flattened with a plate of glass. The effect of smoothness usually was not noticeable. However, in substances having high metallic reflection, *e.g.*, silicates, carbonates, and sulphates, at 8 to 9 μ (see Table IV, quartz at 8.8 μ), the smoothness of the surface was of importance. For example, a rather coarse-grained sample of powdered feldspar reflected 10.3 per cent. at 8.8 μ. On pressing the material into a more compact mass, the reflecting power arose to 14.6 per cent.

Zirconium oxide mounted by the two methods gave concordant results. Owing to the high reflecting power of the material, so much energy was thrown upon the thermopile that the glass window, which absorbs about 15 per cent. of the radiations at 4.4 μ, became sufficiently warm to cause the galvanometer to drift. It was, therefore, impossible to obtain trustworthy values of the reflecting power of the white powders with the glass window in place. It was, therefore, replaced by a window of rock salt. When examining the black substances at 4.4 μ the opposite condition obtained. In comparison to the total amount reflected, the temperature rise was such that re-radiation from the lampblack became appreciable. The glass window had, therefore, to be used over the thermopile to absorb the radiations from the black substances.

As mentioned elsewhere, there is a distinction between the high reflecting power observed at 4.4 μ and at 8.8 μ. The high values (40 to 50 per cent.) at 4.4 μ are to be ascribed to internal

reflection. On the other hand, it is a common property of insulators to be very opaque beyond 5 μ, and to have bands of selective reflection beyond 6 μ. For example, carbonates have bands of selective reflection in the region of 6.9 μ; sulphates

TABLE IV.

REFLECTING POWER OF PIGMENTS.

Wave-length. λ max.	.54μ	.60μ	.95μ	.95μ (red glass)	4.4μ	8.8μ	24.μ
	%	%	%	%	%	%	%
Cobalt oxide (Co_2O_3).....		3.02	3.92 4.04 2.49		13.9	14.6 11.8	5.9
Copper oxide (Cu O).....			23.5		15.2		4.4
Chromium oxide (Cr_2O_3).....	24.1	27.0	44.6		32.9	5.0	8.2
Lead oxide (PbO).....		51.8			50.6	25.6	9.5
Red iron oxide (Fe_2O_3).....		26.3	41.0	53.6	29.9	3.7	9.1
Yttrium oxide (Y_2O_3).....		73.8			34.4	11.1	10.
Lead chromate ($PbCrO_4$).....	61.2	70.2			41.2	4.74	7.4
Aluminum oxide (Al_2O_3).....		84.1	87.7		20.8	2.34 1.64	6.5
Thorium oxide (ThO_2).....		86.1			46.9	7.11	10.
Zinc oxide (ZnO).....		82.2	86.4		8.5	3.2 2.1	5.1
Magnesium oxide (MgO).....		86.3			16.0	2.5	9.1
Calcium oxide (CaO).....		85.4			22.3	3.6	6.2
Zirconium oxide (ZrO_2).....	82.2	85.8		83.0			
			84.1		23.2	5.1	5.4
Lead carbonate ($PbCO_3$).....		88.7 89.9	90.8 92.8 94.5		29.2	8.3 13.2	6.9
Magnesium carbonate ($MgCO_3$)		85.2	89.4		10.8	4.1	8.8
White paper.....			75.2		18.2	5.0	
Feldspar ($KAl\ Si_3O_8$).....			86.7		38.2	10.3 14.6	9.7
" (cleavage).....		39.4					
Bluestone (sandstone) (SiO_2)..			18.4		8.1	17.6	11.0
Quartz (powdered French flint) (SiO_2).....			81.0		41.5	7.9 13.4	9.0

and silicates have bands of strong selective reflection in the region of 9 μ. Hence, the high reflecting powers observed in the case of carbonates and silicates (Table IV) at 8.8 μ are due to selective reflection from the surface of the particles.

The low reflecting power of the aluminum oxide at 8.8 μ is of interest, because the observations were made in the region of anomalous dispersion where the reflecting power is abnormally

low,[19] followed by bands of metallic reflection at 12 to 14 μ. Zinc oxide also has a low reflection at 8.8 μ. The reflecting power of a plane, highly-polished surface is low and uniform throughout this region.[20] By pressing the powdered material into a smooth, compact mass the reflecting power (3.2 per cent.) was not materially increased. This shows that it is not a surface phenomenon, as found in silicates and carbonates. For example, in lead carbonate which was pressed into a smooth, hard mass, comparable with that of the zinc oxide sample just mentioned, the diffuse reflecting power was raised from 8.3 to 13.2 per cent. These surfaces, including zirconium oxide, which has a low reflecting power, appeared dull at normal incidence; but when viewed at grazing incidence appeared like highly-polished mirrors. The difference between "surface color" and "body color" is well illustrated in lead carbonate and in zinc oxide.

Lead oxide appears to have an extremely high reflecting power in the region of 8.8 μ, and by using a plane, highly-polished surface the reflection spectrum of this substance should be examined for residual rays in the region of 8 to 10 μ.

Many of the substances examined show a high reflecting power for the spectral region of 24 μ, from which it is to be inferred that they possess strong selective reflection in this region of the spectrum. It is, of course, already known that carbonates and silicates have bands of selective reflection in this region of the spectrum.

Mention was made in the beginning of this paper that the most efficient paint to protect a building from solar rays is one having a high reflecting power in the visible spectrum and a low reflecting power in the region of 8 to 9 μ. Of the various materials used in paints, zinc oxide would be the most efficient radiator in the region of 8 to 10 μ, but it does not appear to reflect so highly as lead carbonate in the visible and the violet. Mixed with an oil, however, the lead paint does not appear so white; and it has a lower emissivity at 8.8 μ. Hence, from a radiometric standpoint, pure zinc oxide and lead carbonate appears to be the most promising paint. But the use of mixtures

[19] See "Investigations of Infra-red Spectra," Publication No. 97, p. 18, Carnegie Institution, 1908.

[20] Carnegie Publication, No. 97, p. 17.

of calcium carbonate (carbonates), calcium or barium sulphates (sulphates), China clay, or silica (silicates), which are often mixed with these primaries,[21] *e.g.*, with zinc oxide, does not appear advisable, viewed from a radiometric standpoint, for they all indicate a low emissivity in the infra-red. In the complete research it is purposed to include measurements on various samples of white paints.

TABLE V.

MISCELLANEOUS SUBSTANCES.

Wave-length. λ max.	.60μ	.95μ	4.4μ	8.8μ
	%	%	%	%
Brick:				
Light buff	48.4			
Darker	40.0			
Red brick	30.1			12.4
Darker and glazed	23.4			
White marble ($CaCO_3$); ground; unpolished	53.5		6.4	5.1
" " " " (cleavage)	40.8			
Indiana limestone ($CaCO_3$)	42.9		20.3	5.0
Granolith (pavement)	16.9			
Asphalt	14.8			
" (free from dust)	7.2			
Slate (dark clay)	6.7			20.0
Brown sand	25.7			
Black velvet	1.75		3.66	2.7
Black felt	13.9	21.2		
Deep blue (navy department)	17.0			
Lighter shade	18.2			
Blue flannel	17.5			
Leaf (tulip tree)	21.9	38.0	5.6	

VIII. REFLECTING POWER OF MISCELLANEOUS SUBSTANCES.

In Table V are given the data obtained on various substances not closely related to the groups of substances already described. The ground and the cleavage surface of white marble illustrate the effect of grain size upon the reflecting power, as mentioned in the beginning of the paper. The brown sand examined illustrates the average reflection from material obtainable along roadsides. Fine dust would probably have a higher reflection. The effect of fine dust upon asphaltum is also shown in this table. The sample examined was a piece of road material which

[21] *Proc. Amer. Soc. for Testing Materials*, 11, p. 226, 1911.

was being removed after some years' usage. In the same manner the granolith was a piece of pavement. The latter sample, however, was washed and free from dust. Of the other building materials the slate used in roofing is of interest, for it reflects only about 6.7 per cent. of the solar rays.

For convenience in tabulating, the data on "bluestone" (the dark-colored sandstone extensively used in buildings) are given in Table IV. This material cleaves into thin, flat laminæ. The reflecting power at 8.8 μ and 24 μ is very high, owing to the bands of selective reflection (silica) and the presence of fine crystal surfaces. The reflecting power of powdered feldspar and of quartz ("French flint") is also given in Table IV.

Black velvet has a very low reflecting power. The reflecting power of the sample of black felt recorded in Table V was examined several times on different days. The values were always high. In comparison, visually, with the black velvet the sample appeared much lighter in color.

WASHINGTON, D. C., Oct. 5, 1912.

Lignite in Tuscany. ANON. (*Mon. Sci. Mercure,* ii, 848, 61.)—The deposits of lignite in Tuscany are of great importance to the whole of Italy, for the beds at San Giovanni, 45 kilometres (28 miles) from Florence, furnish two-thirds of the total supply. The content of these beds is estimated at 8,000,000 tons. The product contains 40 to 45 per cent. of water and has a calorific power of 3,400 calories in the dry condition. It is marketed in the form of briquettes. In 1909 there were 176,490 tons sold.

Protecting Iron and Steel from Corrosion. ANON. (*Brass World,* viii, 8, 272.)—Gilbert Rigg, of the New Jersey Zinc Company, has discovered that sodium tungstate prevents the rusting of iron and steel. A solution of 1 part of sodium tungstate in 2,000 parts of water is efficient. This is applied to zinc oxide paints, and zinc tungstate is ground with the paint and protects iron and steel.

Colloid Phenomena in Concretions. E. GEINITZ. (*Centr. Min.,* 1912, 282.)—The concentric structure of clay-stone concretions, and the striated cylindrical masses observed in flint and usually regarded as problematical organisms, are most readily explained as the result of diffusion in colloid substances, such as has been shown by Liesegang to be the origin of agate structures.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

COMPARISON OF FIVE METHODS USED TO MEASURE HARDNESS.[1]

By Ralph P. Devries,
Assistant Physicist, Bureau of Standards.

In order to ascertain the concordance which might be expected in the five leading instruments for testing the hardness of metals, an investigation was made at the Bureau of Standards, the report of which is about to appear in the series of Technologic Papers of the Bureau. The static tests of hardness studied are the cone and Brinnell Sphere. The dynamic tests are the Shore

HARDNESS NUMERALS OF DIFFERENT METALS BY FIVE METHODS OF TEST.

Metal	Shore scleroscope	Hardness numeral: Brinnell $\frac{P}{2\pi t R^1}$	Brinnell $\frac{P}{t}$	Cone, 90° cone	Test, 60° cone	Bauer drill test	Ballantine test
Carbon steel	86.1	641	4550	.....	.....	.....	3.2
Silicon steel	33.6	261	865	331	130	.....	3.0
Manganese steel	29.5	179	641	368	124	.....	3.3
Cast iron No. 1	33.3	149	538	191	68	.....	3.2
Cast iron No. 2	32.9	172	590	231	79	2.29	3.3
Bessemer steel	26.6	188	428	260	76	.....	3.3
Tool steel	37.8	289	1230	.....	.....	.....	3.3
Cu.-sn. alloy 1	42.4	110	460	130	50	.73	3.1
Cu.-sn. alloy 2	25.5	105	323	149	54	1.04	3.2
Cu.-sn. alloy 3	22.1	94	289	122	48	1.24	3.4
Copper 4	15	89	235	114	38	1.88	3.2

Scleroscope, Brinnell Sphere, and Ballantine. The Bauer Drill test for measuring the work-ability of metals is also included. The tests were made on a series of metals which ranged from very hard steels to comparatively soft alloys. The laws governing the resistance to indentation are experimentally deduced for spheres of different sizes and cones of different degrees of angular open-

[1] Abstract of Technologic Paper of the Bureau of Standards, No. 11 (in press).

ing. The effect of elastic deformation of the sphere upon the results of sphere tests is determined by means of a method which involves the exact measurement of the depth of indentation. This method of measurement is also applied to the cone tests. The study of the individual methods shows (1) the possibility of obtaining rational hardness numerals for the cone and sphere tests, and (2) that the dynamic tests for hardness do not agree in general with the results of static tests.

SODIUM OXALATE AS A STANDARD IN VOLUMETRIC ANALYSIS.[1]

THIS circular gives a *résumé* of the work done on sodium oxalate at the Bureau of Standards and elsewhere which has led to its selection by this Bureau as a primary standard in volumetric analysis. This material is now issued in a form similar to other standard analyzed samples, of which about forty have already been prepared for distribution to the public. The circular describes the methods of preparation, and testing of the sodium oxalate. Its stability is discussed, as well as its uses in oxidimetry and acidimetry, although it is especially recommended as an oxidimetric standard.

INSTRUMENTS AND METHODS USED IN RADIOMETRY.[2]

By W. W. Coblentz,
Associate Physicist, Bureau of Standards.

IN this paper is given an account of the recent development and improvement of spectral radiation instruments. This includes air and vacuum bolometers, thermopiles, and radiomicrometers; new combinations of instruments; linear and surface thermopiles of bismuth-silver of high sensitivity; and (Note I) the Callendar radio-balance.

[1] Abstract of Circular of the Bureau of Standards, No. 40 (in press). Copies may be obtained upon application.

[2] The full paper will be found in *Bulletin of the Bureau of Standards*, vol. ix. Separates may be obtained upon request addressed to the Bureau.

The aim of the research was the production of instruments of precision rather than the attainment of high sensitivity. The vacuum bolometer was found to excel all the other types of radiometers in accuracy in speed and in range of sensitivity. The instrument is difficult to handle, and for most work the bismuth-silver thermopile is recommended. The latter is as sensitive as a bolometer. The novelty of this type of thermopile is the solid surface which is exposed to radiation, thus utilizing all the energy from a spectral line with the type of iron-constantan thermopile in present use. The various modifications of these thermopiles are applicable to radiation pyrometers, sunshine recorders, and thermogalvanometers for measuring weak alternating currents.

THE PHYSICAL TESTING OF MECHANICAL RUBBER GOODS.[1]

THIS circular outlines the methods used at the Bureau of Standards for determining the physical properties of rubber, and gives a brief description of the processes of manufacture, beginning with the collection of crude rubber, and also processes for reclaiming rubber. The tension test is the most widely applicable, being used to determine the more important physical properties, such as elasticity, strength, and ultimate elongation. Machines and apparatus for conducting these tests have been designed and constructed at the Bureau of Standards. The apparatus for determining elasticity is adapted to test six samples at once, thus introducing considerable saving of time over the method usually followed. This test consists in stretching specimens to a definite elongation and measuring the permanent extension or set after a specified interval of rest. A similar piece of apparatus has been designed for determining the reduction in tension when rubber is stretched and held at a definite elongation. Motor-driven machines with a number of speeds are used for testing tensile strength and ultimate elongation, and on all testing machines a specially-designed grip is used for holding the specimen.

In preparing samples for test a die is used which insures uniformity of size. Gauge marks are placed on the test piece from which the permanent set and ultimate elongation are meas-

[1] Circular No. 38, Bureau of Standards.

ured. Results of tests are shown graphically, illustrating the characteristics of various rubber compounds. The effect of continued heat at 160° F. on different rubbers is shown, and these tests are being extended with a view to establishing an accelerated aging test. An analysis of the distribution of stress in a ring test piece is given showing that as a result of the uneven distribution of stress the ring method does not develop the full tensile strength of rubber. This theory is verified by the results of tests which are given in tabular form.

DETERMINATION OF MANGANESE AS SULPHATE AND BY THE SODIUM BISMUTHATE METHOD.[1]

By William Blum.

OF the three forms most commonly used for the gravimetric estimation of manganese, that depending upon weighing as Mn_3O_4 is generally admitted to be inaccurate; while, as shown by Gooch and Austin, the composition of manganese pyrophosphate, obtained by ignition of the manganese ammonium phosphate, depends very directly upon the conditions of precipitation, and usually yields high results under the conditions recommended by them. Manganous sulphate is, therefore, the only compound adapted to accurate weighing of this element, either in gravimetric analysis or in obtaining a definite amount of manganese as a primary standard. Of the various volumetric methods considered, the bismuthate method appeared to be most nearly free from the influence of the precise conditions of operation, and therefore most suitable for use as a standard method.

This method depends upon the oxidation of manganese to permanganic acid by sodium bismuthate in nitric acid solution. After filtration through asbestos to remove the excess of bismuthate, ferrous sulphate is added in slight excess, which is then titrated with permanganate of known manganese value and of known ratio to the ferrous sulphate. The method of standardizing the permanganate is, of course, fundamental, and forms the principal subject of this paper. The manganese value may

[1] Abstract of Scientific Paper No. 186. The full paper will appear in the *Bulletin of the Bureau of Standards*, and separates may be obtained upon application.

be determined by two general methods: (*a*) titration of a known amount of manganese, *e.g.*, as $MnSO_4$, under the conditions of operation; and (*b*) calculation from the oxidizing value of the permanganate, derived from some accurate oxidimetric standard, such as sodium oxalate. The former would be more satisfactory, provided a simple and accurate means of obtaining a known amount of manganese is available. Otherwise the latter is preferable, though it involves the use of a conversion factor, which may be either theoretical or empirical.

The author employed sodium oxalate for this purpose and used the theoretical conversion factor, after having shown that if a given amount of permanganate be reduced and reoxidized by bismuthate it is equivalent in oxidizing power to the original permanganate. Since, however, Brinton and others claimed that the sodium oxalate values were one per cent. lower than those derived from manganous sulphate, the subject was studied in further detail. Special precautions were observed in the preparation and preservation of the materials and solutions, and the titrations were conducted entirely with weight burettes. A study of the standardization of permanganate with sodium oxalate showed that the conditions recommended by McBride must be slightly modified for use with 0.03 N permanganate, the strength usually employed for the bismuthate method; since the relative errors caused by variation in conditions with 0.03 N permanganate may be much larger than with 0.1 N. By the use of a small volume in the titration the errors from this source are reduced to a minimum.

Results obtained by evaporation of a manganous sulphate solution depend entirely upon the time and temperature of the final heating, which point was investigated. It was found that heating for a considerable period at temperatures of 450–500° is necessary to obtain anhydrous normal manganous sulphate, and that the salt begins to decompose at temperatures from 550°–600°, *i.e.*, incipient to dull red heat. Solutions of known manganese content were prepared by solution of a definite weight of manganous sulphate which had been heated to constant weight at 450°–500°.

A study of the effect of conditions upon the bismuthate oxidation showed that for amounts of manganese up to 0.05 gramme accurate results may be obtained over a wide range of

conditions, viz., at from 5° to 25° in a volume of 50 to 150 c.c., containing 20 to 40 per cent. nitric acid by volume, filtration after standing one-half minute or one-half hour with bismuthate; addition of ferrous sulphate immediately or after one-half hour. The results were accurate in the presence of as much as three grammes of iron. Addition of phosphoric acid to the ferrous sulphate solution rendered the end points more distinct. The only conditions found which yielded inaccurate results were (*a*) deficiency of nitric acid, (*b*) failure to agitate after addition of bismuthate, and (*c*) allowing the solution to stand after addition of the excess of ferrous sulphate. For analyses of rich ores and similar high-grade materials, the use of 0.1 N permanganate is recommended, permitting the use of about 0.1 gramme sample.

Experiments upon seven permanganate solutions, of different strengths (0.03 N and 0.1 N), prepared from different sources, showed that the values derived from sodium oxalate and manganous sulphate agreed in every case to within one part in five hundred. The accuracy of these values was confirmed by analysis of specially purified potassium permanganate crystals and by additional experiments upon the reduction and reoxidation of permanganate solutions. Comparative analysis of the Bureau of Standards manganese ore, as well as other ores, showed that the tendency of many of the commercial methods is to yield high results for manganese.

The bismuthate method is recommended as equal or superior to any other known methods for the determination of manganese, whether present in large or small amounts.

Active Modification of Nitrogen Produced by the Electric Discharge. R. J. STRUTT. (*Roy. Soc. Proc., Ser. A.*, lxxxvi, 262.)—The conclusions reached are: (1) Active nitrogen emits its energy more quickly and reverts sooner to ordinary nitrogen if it is cooled. This is apparently a unique instance of a chemical change accelerated by cooling. (2) If the glowing gas is compressed to a small volume, it flashes out with great brilliance and exhausts itself. This proves that the glow-transformation is polymolecular; *i.e.*, that more than one molecule must take part in it. (3) Active nitrogen may revert to ordinary nitrogen in two distinct ways. One is a volume change accompanied by glow, the other a surface action of the walls of the vessel without glow. This is analogous to the behavior of oxyhydrogen gas in its transformation to water, which may be either a surface or volume effect.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, October 16, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 16, 1912.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 25.

Mr. Robert S. Perry was elected to fill a vacancy existing on the Board of Managers.

Following the meeting of the Institute for the transaction of this business, a joint meeting was held with the Philadelphia Section of the American Institute of Electrical Engineers.

President Clark introduced Mr. H. Clyde Snook, President of the Roentgen Manufacturing Company, Philadelphia, and then called on Mr. H. A. Hornor, Chairman of the Philadelphia Section, to preside.

Mr. Snook presented the paper of the evening, entitled "Recent Developments in Radiography."

The speaker reviewed the improvements made during the past several years in X-ray apparatus, and described the various devices used by the radiographer. Considerable attention was given to the several portable X-ray outfits intended especially for use in the army and designed to be transported by horse-drawn or motor-propelled vehicles.

Numerous lantern slides of radiographs and apparatus were shown, and several demonstrations were made on a complete X-ray apparatus especially installed for the purpose. First announcement was made of a new form of X-ray tube with a radium regulator. In this device clevite, an ore of uranium, is decomposed by the action of the current and emanates gaseous helium, which in turn regulates the vacuum in the tube.

The paper was discussed by Mr. Stratton, Dr. Goldsmith, Mr. Hornor, and others.

At the close of the discussion President Clark extended the thanks of the Institute and Mr. Carl Hering the thanks of the Philadelphia Section of the American Institute Electrical Engineers to the speaker.

The meeting then adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, October 2, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 2, 1912.

MR. WILFRED LEWIS *in the Chair.*

The following report was presented for reconsideration:

No. 2514—Kennicott Water Weigher. Scott Award confirmed.

The following report was presented for final action:

No. 2513—McKee's Printing Plate and Process. Scott Award. Adopted.

The following report was presented for first reading:

No. 2499—Santo Vacuum Cleaner.

The following application was accepted for examination:

No. 2520—De Vos's Rolling Sector Boat-Davit.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, October 3, 1912, at 8 o'clock P.M., with Dr. George A. Hoadley in the chair.

The Chairman introduced Prof. Robert Kennedy Duncan, Director Industrial Research and Professor of Industrial Chemistry, University of Pittsburgh, Pittsburgh, Pa., and University of Kansas, Lawrence, Kan., who delivered a lecture on "Industrial Research."

Among other examples of the fruits of industrial research, Dr. Duncan mentioned those of the discoveries of methods of producing synthetic rubber and synthetic indigo. He spoke of the large field of discovery still open to the experimentalist with waste products, etc.

Following his lecture, Dr. Duncan outlined the scheme of research fellowships in operation at Pittsburgh and Kansas under a system inaugurated by himself some six years ago and now grown to large proportions.

The thanks of the meeting were extended Dr. Duncan.

Adjourned.

R. B. OWENS,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, October 10, at 8 o'clock P.M., with Mr. George R. Henderson in the chair.

The Chairman introduced Professor Gaetano Lanza, of The Baldwin Locomotive Works, who read a paper on "The Testing of Full-Size Pieces under Practical Conditions, Together with Locomotive Testing in the United

States." The paper was illustrated by lantern slides and discussed by several members and visitors.

Mr. Waring, of the Pennsylvania Railroad Company, Altoona, Pa., was introduced by the Chairman and described some of the special slides shown.

The thanks of the meeting were extended to Professor Lanza.

Adjourned.

FRANK B. STEM,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. WM. FRY JAMES, 6920 Boyer Street, Mt. Airy, Philadelphia, Pa.
MR. FRANK STEM, 608 Chestnut Street, Philadelphia, Pa.

NON-RESIDENT.

MR. F. S. STEVENS, Philadelphia & Reading Railway Company, Reading, Pa.
MR. C. D. YOUNG, Pennsylvania Railroad Company, Altoona, Pa.
MR. J. H. FULMOR, Pennsylvania Railroad Company, Pottsville, Pa.
MR. C. M. HARRIS, The Washington Terminal Company, Washington, D. C.
MR. J. TURNER MOORE, President Reading-Bayonne Steel Casting Company, Reading, Pa.
MR. NATHAN C. JOHNSON, 109 Luzerne Avenue, Pittston, Pa.
PROF. L. A. HERDT, McGill University, Montreal, Canada.
MR. G. W. CHANCE, Bristol, Pa.

ASSOCIATE.

MR. FRANKLIN P. MCCONNELL, 100 South Fourth Street, Darby, Pa.

Changes of Address.

MR. MORRIS KNOWLES, 2548 Oliver Building, Pittsburgh, Pa.
MR. HORACE C. KNERR, Wirt Electric Specialty Company, Primos, Pa.
PROF. J. AMBROSE MOYER, State College, Pa.
MR. E. E. KELLER, care of Detroit Insulated Wire Company, Wisson Avenue, Detroit, Mich.
MR. COLEMAN L. NICHOLSON, 117 Argyle Road, Ardmore, Pa.
MR. C. R. COLLINS, Hoge Building, Seattle, Wash.
PROF. L. F. RONDINELLA, High School for Boys, Forty-eighth and Walnut Streets, West Philadelphia, Pa.
PROF. L. M. HAUPT, Cynwyd, Pa.
MR. GEORGE MACLEAN, 18 West Thirty-fourth Street, Astor Court Building, New York City, N. Y.
MR. ARTHUR R. EDGERTON, Gardiner, Douglas County, Oregon.
J. M. GAZZAM, ESQ., 265 South Nineteenth Street, Philadelphia, Pa.
MR. KERN DODGE, Morris Building, Philadelphia, Pa.

MR. HAROLD M. BUSH, 136 East Gay Street, Columbus, Ohio.
MR. T. BROOM BELFIELD, 1905 Spring Garden Street, Philadelphia, Pa.
REAR ADMIRAL JOS. B. MURDOCK, U.S.N., General Board Navy Department, Washington, D. C.
MR. CHARLES E. HUBSCH, 2019 South Eighteenth Street, Philadelphia, Pa.
MR. LOUIS B. WHITNEY, Room 2444, Henry W. Oliver Building, Pittsburgh, Pa.
MR. CHARLES H. FISH, P. O. Box 1593, Boston, Mass.
MR. MARK W. MARSDEN, Logan Station, Philadelphia, Pa.
MR. BENJ. W. CARSKADDON, 42 North Owen Avenue, Lansdowne, Pa.
MR. JOS. S. HEPBURN, Columbia University, Department of Biological Chemistry, 437 West Fifty-ninth Street, New York City.
MR. LIGHTNER HENDERSON, 1515 Monroe Building, Chicago, Ill.
MR. G. H. CALKINS, 10th Floor Electric Building, Buffalo, N. Y.
REAR ADMIRAL JOHN R. EDWARDS, U.S.N., President Board of Inspection, for Shore Station, Navy Department, Washington, D. C.
MR. WILLIAM G. ROGERS, 2131 Pacific Street, Philadelphia, Pa.
MR. C. W. ALLEN, 523 Oley Street, Reading, Pa.

NECROLOGY.

John Thomas Killé, a veteran of the iron industry and life member of the Institute, passed away on June 18, 1912, over 92 years of age. He was a native of Philadelphia, born in the southern section of the city, May 31, 1820. He was given a careful education in private schools, where he evinced a special aptitude for linguistics, acquiring, in his school years, a fluent mastery of French, and subsequently an almost equal proficiency in German and Italian. His active life began at an early age with the management, after his father's death, of the family interests in a wholesale dry goods house and in some cotton mills in Manayunk, in which connection he gave proof of business ability of a high order. These abilities opened the way to his being chosen, early in 1855, as secretary and treasurer of the Cambria Iron Works, under the presidency of Charles W. Wood. He continued in both capacities through a quarter of a century and as treasurer of the corporation through another ten years, retiring in 1890, after nearly a half-century of active business life. The qualities of direction and conservation, of forcefulness and foresight, demanded in the upbuilding of a great industrial organization like the Cambria Iron Works, were contributed in ample measure by its secretary-treasurer. Of the belching smokestacks that withstood the raging flood at Johnstown, and that are still telling of the industrial life below, some of the most prominent may be regarded as monuments to the sagacity, the industry, and the honesty of John Thomas Killé.

In The Franklin Institute this thoughtful worker also has a monument in the work of advancement which his generous bequest is helping to enlarge.

L. E. L.

Mr. James Rawle was born at Lancaster, Pa., in 1842. He was graduated a Bachelor of Arts from the University of Pennsylvania in 1861, and received his Master's Degree in 1864. He adopted the profession of civil engineer, and from 1862 to 1865 was a member of the corps on the construction of the Philadelphia and Erie Railroad.

He became connected with the J. G. Brill Company, of Philadelphia, in 1872, and was for many years its secretary and treasurer. On the death of George M. Brill, in 1906, he was elected president of the establishment. His death occurred on May 1, 1912, at Bryn Mawr, Pennsylvania.

Mr. Rawle was a director of many Philadelphia banks, and was for several years an officer of the First Troop, Philadelphia City Cavalry. He was elected to membership of The Franklin Institute in 1903.

Mr. John Alwine, Jr., Baltimore, Md.
Mr. Wm. R. Beal, Newburgh, N. Y.
Major Wm. H. Lambert, Mutual Life Building, Philadelphia, Pa.

LIBRARY NOTES.

Purchases.

ADAMS, H.—Theory and Practice in Designing. 1911.
SMITH, G. F. H.—Gem-stones. 1912.
RECORD, S. J.—Identification of the Economic Woods of the United States. 1912.
DANA, R. T., and W. L. SAUNDERS.—Rock Drilling. 1911.
HUDSON, C. W.—Notes on Plate Girder Design. 1911.
POTTS, H. E.—The Chemistry of the Rubber Industry. 1912.
BRISLEE, F. J.—An Introduction to the Study of Fuel. 1912.
FREITAG, J. K.—Fire Prevention and Fire Protection. 1912.
FOURNIER D'ALBE, E. E.—Contemporary Chemistry. 1911.
SCHNEIDER, N. H.—Dry Batteries. 1910.
SCHNEIDER, N. H.—Modern Primary Batteries. 1910.
INGALLS, J. M.—Interior Ballistics. 1912.
LUCKE, C. E.—Power. 1911.
CHALKLEY, A. P.—Diesel Engines for Land and Marine Work. 1912.
CHAPIN, H. M.—How to Enamel. 1911.
KERSHAW, J. W.—Elementary Internal Combustion Engines. 1912.
BOOTH, W. H.—Liquid Fuel and its Apparatus. 1912.
CARSLAW, H. S.—Introduction to the Theory of Fourier's Series and Integrals. 1906.
ROSCOE, H. E., and C. SCHORLEMMER.—A Treatise on Chemistry, vols. 1 and 2, ed. 4. 1907 and 1911.
NORTH, S. H.—Oil Fuel. 1910.
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CURRENT TOPICS

Preservation of Mine Timbers. ANON. (*J. Mines Met.*, 1, 5.)—The value of timber for mines depends on its strength, and this article gives the crushing strength of many kinds of timber. It is shown that very dry wood has a crushing strength 40 per cent. higher than wood in the ordinary condition of dryness. As most mines are damp, attempts are made to keep the timbers dry by impregnating them with metallic salts or tar derivatives, but without marked success. The salts wash out and the tar compounds keep the wood constantly damp. The merits of "Aczol," a metallic phenate, are discussed, and it is claimed that it increases the resistance of the wood, prevents the absorption of moisture, and acts as a germicide.

New Process of Seasoning Wood. ANON. (*Engineer*, cxiii, 463.)—A tank filled with a solution containing 5 per cent. resin, 10 per cent. borax, and a little sodium carbonate has on its bottom a lead plate connected to the positive pole of a dynamo. Timber is stacked on the plate till the tank is full; another lead plate is superimposed and connected to the dynamo. On passing a current sap is driven out, and the resin and borax take its place. The results are claimed to be highly satisfactory even with green timber.

Geological Formation of Tin Deposits. H. G. FERGUSON and A. M. BATEMAN. (*Econ. Geol.*, vii, 209.)—The distribution of the tin deposits throughout the world, and the geology, are discussed. Tin deposits are associated with acid intrusives and may vary in age from Archean to late Tertiary. The most important of its mineral associates are quartz, feldspar, mica, tourmaline, pyrite, arsenopyrite, and topaz, fluorite, etc. The formation of the cleavages may be considered one of the last phases of the work of the acid extract in the magma. It involves the addition of silica, boric acid, fluorine, and tin oxide, and often of lithium oxide, potassium oxide, and alumina, and the abstraction of the oxides of calcium, magnesium, and sodium, and sometimes of potassium and aluminum. The formation of the cassiterite itself, which occurs by the reaction, $SnF_4 + 2H_2O = SnO_2 + 4HF$, may have taken place under various conditions. Cassiterite may be found, (1) as an original constituent of granite and pegmatite, (2) as a result of pneumatolysis and pneumatolytic metasomatism, (3) as a true contact metamorphic mineral, (4) deposited under hydrothermal conditions or (5) at atmospheric pressure in the deposits of thermal springs.

Steel. J. W. RICHARDS. (*Met. Chem. Eng.*, x, 265.)—The proposal is made that "steel" be the generic name for all varieties of usefully malleable iron with less than 2.2 per cent. of carbon. This term would then include wrought iron, puddled steel, blister steel, cemented bar, single—and double—shear steel, ingot iron, soft steel, mild steel, C steel, and alloy steels. The iron of commerce would then be divided; that which is usefully malleable being known as "steel," and what is not usefully malleable known as "cast iron."

Production of Hydrogen. LEPSIUS. (*J. Gas Lighting*, cxvii, 896.)—The method pursued on a manufacturing scale at the Chem. Fabrik Griesheim-electron is the electrolysis of a solution of sodium chloride. A diaphragm of cement, not attacked by chlorine and alkali, is used, and the electrodes are iron and carbon plates. The hydrogen is obtained as a by-product in the manufacture of chlorine, according to the reaction:

$$2NaCl + H_2O = Na_2O + 2Cl + H_2.$$

One ton of salt yields 7,000 cubic feet of hydrogen. The Griesheim works, using 15,000 horse-power, produce 6 tons, or 245 million cubic feet of hydrogen per annum.

Yellow Flame Arcs. M. SOLOMAN. (*Electr.*, lxix, 130.)—The success of the flame arc is due more to Bremer and to other carbon producers than to the arc lamp manufacturers. The cores are made by mixing finely-ground carbon and fluoride with a potassium silicate solution, pressing it into a core canal, and drying. In standard carbons the core mixture is 50 per cent. fluoride, giving the total fluoride equal to about 12–15 per cent. Calcium fluoride, cerium fluoride, and strontium fluoride are used to produce yellow, white, and red arcs respectively. The conductivity of the carbon is increased by a metal core. Different types of lamps and carbons are compared as to cost per hour and efficiency, showing the behavior of the lamps at various values of voltage and ampèrage. An ordinary negative carbon gives the best results. When carefully compared on the cost per candle-hour basis, the cost of metal cored and plain carbons is about equal.

Brownian Movements. S. LIFCHITZ. (*Comptes Rendus*, cliv, 1084.)—It has been previously shown that the phenomenon of Bjerknes was insufficient to explain the displacement of particles of smoke by a condenser spark discharge. In this paper the eddies caused by the spark are investigated. Photographs are shown of the case when the "acoustic" oscillations were equal to 6.8 millions per second. Certain points on the axes of the whirlpools are apparently stationary and others move appreciably. At lower frequencies the trajectories have greater curvature, and the explosions produce a general displacement of all the particles.

Distribution of the Active Deposit of Radium in an Electric Field. E. M. WELLISCH and H. L. BRONSON. (*Phil. Mag.*, xxiii, 714.)—These experiments to explain the mechanism involved in the transmission of the active deposit of radium to the electrodes in an electric field, or to the exposed solid surfaces in the absence of such a field, show a decided interaction between the "restatoms" and the ions produced by the radiations which accompany the formation of these particles. There appear to be no negatively-charged carriers, all the so-called anode activity being due to the diffusion of uncharged carriers. The effect on the distribution of the passage of Röntgen rays through the gas is appreciable only when the activity and ionization are far from saturation. Lack of agreement in the results of previous investigations is traced to the fact that the potentials employed were often far from sufficient to satisfy the radioactive ions. The difficulty of obtaining saturation both for cathode activity and for α-ray ionization is explained by the hypothesis that the α-particles produce "neutrons," *i.e.*, molecules in an electrically neutral but unstable condition, some of which are subsequently resolved into ions, probably by collision with ions already produced in the ionization columns.

The "Luminator" Treatment of Water. H. B. LAKE. (*J. Soc. Chem. Ind.*, xxxi, 57.)—Very hard water was passed through tubes and V-shaped troughs of aluminum at different rates and under different conditions of light. Determinations of total and permanent hardness, "soluble" and "insoluble" calcium and magnesium, sulphates and carbonates, failed to reveal appreciable change in the condition of the water, and it is concluded that the process causes no considerable reduction in the resultant salts, either as combined salts or in the "ionic" state.

Theta Tubing. ANON. (*Amer. Mach.*, xxxvi, 14, 551.)—Jacobs's theta tubing is a special-shaped tube, which combines maximum strength with minimum weight. Very desirable qualities for bicycle and motorcycle frames, aëroplane frames, and other light vehicles, which require more strength than the present round tubing affords. Theta tubing is so-called because its cross-sectioned shape resembles the Greek letter θ. The tubes are made of sheet alloy steel, which, when oil treated, has its tensile strength increased by 60 to 75 per cent. Two sheets are bent over mandrels to approximately the required shape and then welded together; the surfaces are then ground on an emery wheel, making the welded portion as smooth as the rest of the tube. A machine is being designed to roll this tubing out of flat sheets, and another for welding the tubing. This tubing was invented by H. W. Jacobs, assistant superintendent of motive power of the Atchison, Topeka and Santa Fe Railway, and is made by the Air Light Metal Company, Atchison, Kan.

The Behavior of Anomalous Dielectrics. H. JORDAN. (*Deutsch. Phys. Gesell. Verh.*, xiv, 9, 451.)—In this paper the behavior of dielectrics with constant and variable applied voltages is fully investigated. The method of von Schweidler is applied to this investigation, the dielectric forming part of a plate condenser. The rate of charge and discharge with respect to time of a practical condenser charged with a steady pressure differs from the theoretical condenser. The divergence is fully investigated, the condensers used being the ordinary telephone type paper-tinfoil condensers. These condensers were found unsuitable for alternating-current measurements, as they behaved exactly like a cable with the distant end open-circuited. This difficulty was obviated by unwinding the condensers and using such a small portion that it operated as a condenser and the cable effect was no longer evident. The direct-current measurements were taken by means of a continuously revolving commutator arranged to charge the condensers for a definite fraction of a revolution and to discharge for the rest of the cycle, the discharge current being measured at different times of the discharge period by means of a ballistic galvanometer. For the alternating current tests a commercial alternator ($w = 2\pi n = 314$), a small, high-frequency Siemens and Halske generator ($w = 4{,}000$ to $10{,}000$), and for higher frequencies a Poulsen generator, were used. The measurements were effected by the bridge method. The results are plotted in curves, and the original paper should be referred to, as these are not easily abstracted.

Weak Solutions of Radium. H. W. SCHMIDT and H. NICK. (*Phys. Zeitschr.*, xiii, 199.)—The best methods for making standard measurements of radium by the emanation method are described. It has generally been thought that the emanation evolved from weak radium solutions diminishes with time, owing to a supposed absorption of radium by the glass. The authors find no effect of this kind with hydrochloric acid solutions of pure radium or of radium and barium salts. The currents in absolute e. s. units produced per Curie of emanation in various cylindrical ionization chambers were measured and found in good agreement with the values calculated from the empirical formulæ of Duane and Laborde.

Mechanical Model of an Electron. U. CISOTTI. (*N. Cimento*, 2 Ser. vi, 375.)—Beside the rigid electron of Abraham, and the deformable electrons of Lorentz, Bucherer and Langevin, he considers an elastic sphere moving in an infinite liquid and deformed by the pressure of the liquid on its surface. Hence the sphere will become an ellipsoid with its minor axis in the direction of motion. The shortening of the minor axis and the lengthening of the equatorial axis are both proportional to the square of the velocity, and so is the increase of volume.

Change of the Dielectric Constant of Rubber upon the Application of a Tensile Stress Perpendicular to the Lines of Force. L. SCHILLER. (*Ann. Phys.*, xxxv, 931.)—The dielectric constant of a rubber plate was measured by determining the capacity of a condenser formed by the plate and two adjacent metal sheets. The capacity of this condenser was compared with a similar condenser made from a sheet of material of the same thickness and of known dielectric constant. Preliminary experiments show that, in accordance with the general assumption, rubber undergoes deformation without volumetric change, and that its Poisson constant is the same in different directions. The dielectric constant of the rubber decreased when it was stretched in a direction perpendicular to the lines of force; with 30 per cent. elongation the constant decreased from 3.67 to 3.51. The application of the Wiener theory of the dielectric constant of mixtures leads to the conclusion that a state of deformation cannot consist entirely in the anisotropy of the arrangement of molecules which are themselves unchanged. Rather it is to be assumed either that the molecules are stretched in the direction of the tensile stress, or that the molecules, which are already elongated and isotropically arranged, place themselves with their longer axis in the direction of stress.

Volcanoes of Central Madagascar. A. LACROIX. (*Compt. Rend.*, cliv, 476.)—The lavas are of two types, the predominant one being a basaltic series, the other a trachyte series. The former varies from a feldspathic basalt to a melilite; the latter consists of hornblende-rhyolite, biotite-trachyte, riebeckite, phonolite-trachyte, and, finally, phonolite. The theory of the age and the succession of the above lavas is thoroughly discussed.

Influence of Flame Temperature on Incandescence Gas Light. H. STRACH. (*J. Gasbeleucht*, lv, 445.)—The candle-power of upright and inverted incandescence burners was measured with gas containing varying amounts of carbon dioxide. Coal gas containing some carburetted water gas was used. For each series of tests the gas was stored in a holder and mixed with varying quantities of carbon dioxide, and the gross calorific value was determined. In each case the burner was adjusted to give the best effect. With an upright burner the number of calories required per candle-power was 5.78 with gas free from carbon dioxide, 5.71 with gas containing 3.8 per cent., 7.46 with gas containing 11.2 per cent., and 9.85 calories with 21.0 per cent. of carbon dioxide. Similar results were obtained with an inverted burner and with gas enriched with petroleum spirit or acetylene so as to have the same calorific power after the addition of the carbon dioxide. The decrease in the efficiency is due to the fact that gas containing carbon dioxide burns with a larger flame which has a lower temperature.

Increase in Mid-Continent Oil. KANSAS AND OKLAHOMA PETROLEUM PRODUCTION GREATER BY 3,000,000 BARRELS IN 1911 THAN IN 1910, ACCORDING TO UNITED STATES GEOLOGICAL SURVEY.—At least 56,000,000 barrels of oil produced in the Kansas-Oklahoma oil field in 1911 is the estimate of David T. Day, of the United States Geological Survey, against an output of 53,157,386 barrels in 1910. In the Barnsdell and Sinclair pools, in Osage County, Okla., wells of 1,000 to 3,000 barrels daily yield were brought in with sufficient frequency during the year to keep the production of the pool in the neighborhood of 20,000 barrels a day, with a gradual decline toward the end of the year. This new production, together with the increase in the Hogshooter and Pawnee County pools, pushed the output beyond the record in 1910, in spite of the great drought in June and July, which was so severe as to drain the drinking supply of several towns and interfere greatly not only with drilling but with manufacturing enterprises. Several times during the year stocks were drawn upon to slight extent, and increased prices for the oil resulted. Transportation facilities were increased by an 18-inch line built by the Prairie Oil and Gas Company from Turley west twenty miles to Osage Junction. Another 18-inch line was built by the same company from Osage Junction to Cherokee, thirty miles to the northeast. The Texas and Gulf companies also ran lines connecting the Osage pools.

Treatment of Water with Chlorine. J. RACE, F.I.C. (*Jour. Soc. Chem. Ind.*, xxxi, No. 13, 611.)—The use of chlorine as a disinfectant developed entirely within the nineteenth century, immediately after the commercial production of bleaching powder. It was used early in the century for the disinfection of sewage and water, and in 1854 its efficiency was so well recognized that an English royal commission recommended its use for deodorizing the sewage of London. Later it was in practical use in many places in England, Germany, and the United States. Sometimes it is added to the unfiltered water, but that method is wasteful, and there is no doubt that if chlorine is to be employed to the fullest advantage it should be added to the filter effluents. The turbidity, color, and organic impurities of a raw water are not apparently reduced by chlorine, but they are acted upon, with a consequent loss of available disinfectant. The disadvantages of adding chlorine to unfiltered water may be summarized thus: With mechanical filters: Reduced efficiency of chlorine. Slow sand filters: Reduced efficiency of chlorine, and reduced purification by the filters *per se*. When present in water in amounts exceeding one part per million of available chlorine, it can generally be detected by the senses. The taste of chlorine is sharp and acid, and the odor pungent, but these should not be confounded with the sensory characteristics of natural untreated water. Chlorine tends to increase the corrosive properties of water, but in very small amounts this effect is inappreciable.

Exhaust Gas Calorimeter for Internal Combustion Engines. J. S. NICHOLSON and T. R. MORLEY. (*Engin.*, xciii, 721.)—The calorimetric method of measuring the heat contained in the exhaust gases of internal combustion engines, which was adopted by the committee of the Institution of Civil Engineers investigating the efficiency of these engines, is considered unsatisfactory, because the hot gases were mixed with the cooling water. An improved calorimeter is described and illustrated in two forms, which has been used in the James Watt Engineering Laboratories of Glasgow University for about four years with satisfactory results. It is built up of standard pipe fittings; its main principle is that the water and gases are kept separate. The gases flow through a length of Serve tubing, which is surrounded by a pipe of slightly larger diameter, and water is forced through the small concentric space, in a direction opposite to the flow of gas. Thermometers are inserted at suitable places, and the fall of temperature between two thermometers is easily seen. The final temperature of the water and the rate of supply are measured, and the final temperature of the cooled gas, which is compared with the atmosphere.

Nitrates from the Atmosphere. E. K. SCOTT. (*J. Roy. Soc. Arts*, lx, 654.)—This is an account of the progress and present position of the manufacture of nitrogen compounds from atmospheric nitrogen. It is stated that the installations now working the Birkeland-Eyde process have a capacity of 200,000 horsepower, while it is estimated than a further 300,000 horsepower will be at work by 1916. In this process it has been found possible to reduce the size of the absorption towers for the nitrogen peroxide to about one-half by using special earthenware packing instead of pieces of quartz. With regard to calcium cyanimide (nitrolim), the works now in operation and being built have a capacity of over 250,000 tons per annum. Owing to the lack of cheap electrical power this industry has no footing in the United Kingdom.

Determination of Radium in Rocks and Minerals. E. EBLER. (*Chem. Zeit.*, xxxvi, 604.)—The substance is freed from radium emanation by fusion, either alone or with a suitable flux, in a platinum boat, and is then allowed to remain for a definite period, 2 to 30 days, in a closed quartz tube, from which the gaseous contents are ultimately pumped into a gasometer, the material being again fused. From the gasometer the gases are transferred to an exhausted ionization chamber, and the quantity of emanation is determined in the usual way, the amount of radium being found by a comparative experiment with the emanation from a known quantity of radium. Standards may be prepared from radium-barium salts, preferably the oxalates, by carrying out a relative atomic weight determination, by observing the loss of weight on ignition, using a micro-balance.

The Fibre of the Baobab Tree for Paper Making. J. S. REMINGTON, D. A. BOWACK, T. P. HEALD, and A. DAVIS. (*Aynsome Annual,* iii, 62.)—Paper-making trials on a small scale were conducted with the separated bast of the *Adansonia digitata,* or Baobab tree. The commercial bast consists of strips of yellowish-red, interlaced fibrous tissue, clean and well prepared, free from adherent woody matter, and varying in length from 3 to 6 feet. An analysis showed 56.96 per cent. of cellulose, the length of the ultimate fibres ranging from 2.6 to 5.1 mm.: average, 3.6 mm.; the ash was 6.92 per cent. The material is only very slightly lignified, but is rich in pectic matters. The ultimate fibres are smooth, tapered, and rather thin walled, like those of Manila hemp, but broaden out toward the middle in a characteristic manner, sometimes becoming flattened and twisted. The cellulose is separated by a fairly mild treatment, a proportion of 5 per cent. of sodium hydroxide being sufficient, provided a pressure of 5 to 7 atmospheres be employed. Using 7 per cent. of caustic soda, the material yielded 47.5 per cent. of pulp, which was readily bleached by 14 per cent. of bleaching powder, giving a final yield of 42 per cent. of bleached pulp. A digestion by the bisulphite process yielded 44 per cent. of bleached cellulose. These trials showed that the Adansonia fibre is a very valuable material. It readily works "wet" and it blends well with sulphite wood-pulp, imparting strength, rattle, and length of pull; it should be an excellent raw material for tissue papers. The price of the raw bast is somewhat high, but if the sources of supply were more fully developed, it should be brought within practicable limits.

A Naval Architect on Safe Ships. ANON. (*Sci. Amer.,* cvi, 22, 491.)—Otto Kretschmer, Dean of the Marine Engineering Department of the Charlottenburg Technical High School, has drawn attention to his plans for an unsinkable transatlantic ship. This embodies the principle of constructing a hull within a hull. The inner body, which is entirely independent of the outer, contains all the engines and boilers, and it is walled in with steel plating, through which there are no communicating doors between the outer and inner structures. This, as we have shown in these columns, is the only principle of construction on which a practically unsinkable ship can be built.

Burning Pulverized Coal in Smelters and Furnaces. L. S. HUGHES. (*Min. and Eng. World,* April 20, 1912.)—The great drawback to the use of pulverized coal is the damage produced by the formation of a vitrous coating or clinker upon the grate bars, crown sheet, and walls of the firebox, due to the combination of iron oxide with the silica in the coal ash. This production of clinker can be avoided by mixing limestone with the fuel, in a quantity approximately equal to the weight of the coal ash. The mixture is fed into the furnace by a simple air-blast injector.

Volatility of the Platinum Group of Metals. SIR W. CROOKES. (*Roy. Soc. Proc.* A lxxxvi, 461.)—In an electrical resistance furnace, formed of a close helix of platinum strip around a porcelain tube, it was found that the strip thinned and ultimately melted, and on the porcelain tube at the point of rupture a deposit always occurred which consisted of microscopic, hexagonal crystals of platinum. This led to an investigation of the volatility of platinum and its congeners at temperatures below their melting points. The metals were heated in the electric furnace to 1300° C. for successive periods of two hours. The loss of weight was approximately proportioned to the time of heating, and in 30 hours amounted to 0.245 per cent. of its weight for platinum, to 0.745 per cent. for palladium; in 22 hours, to 7.297 per cent. for iridium, and in 30 hours to 0.131 per cent. of rhodium, while ruthenium lost 25 per cent. in 8 hours. With iridium, the amount of loss for equal periods of heating, at temperatures between 1100° C. and 1400° C., increased proportionately to the rise of temperature. After these exposures at 1300° C. the platinum had not sensibly changed in appearance, the palladium gradually lost its smoothness and became crystalline and *moiré*, the iridium showed the same change to a greater degree, the rhodium slightly darkened, but did not become crystalline, and the ruthenium became dull black and was coated with oxide. On repeating the experiments at 900° C. with a Méker burner, these changes only occurred to a very slight degree. In the case of ruthenium, there is no doubt that the volatility is due to the formation of oxide, and probably so in the case of iridium, for a quantity heated to 1300° C. for 30 hours in a quartz tube *in vacuo* lost only 0.069 per cent. Platinum and rhodium, however, appear to volatilize as metal.

The Lohmann Coating for Iron. ANON. (*Met. and Chem. Engin.*, x, 253.)—The Lohmann process, adopted by the Brier Hill Steel Company, of Youngstown, Ohio, resembles the old, hot, galvanizing process. The metal is pickled in sulphuric acid and then passed into the Lohmann bath, which contains hydrochloric acid, mercury bichloride, and ammonium chloride. The dried metal is afterwards immersed in the fused alloy; the mercury is stated to volatilize, and the alloy enters the pores thus formed. Zinc, lead, and alloys of these two metals, with or without tin, are said to adhere well.

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